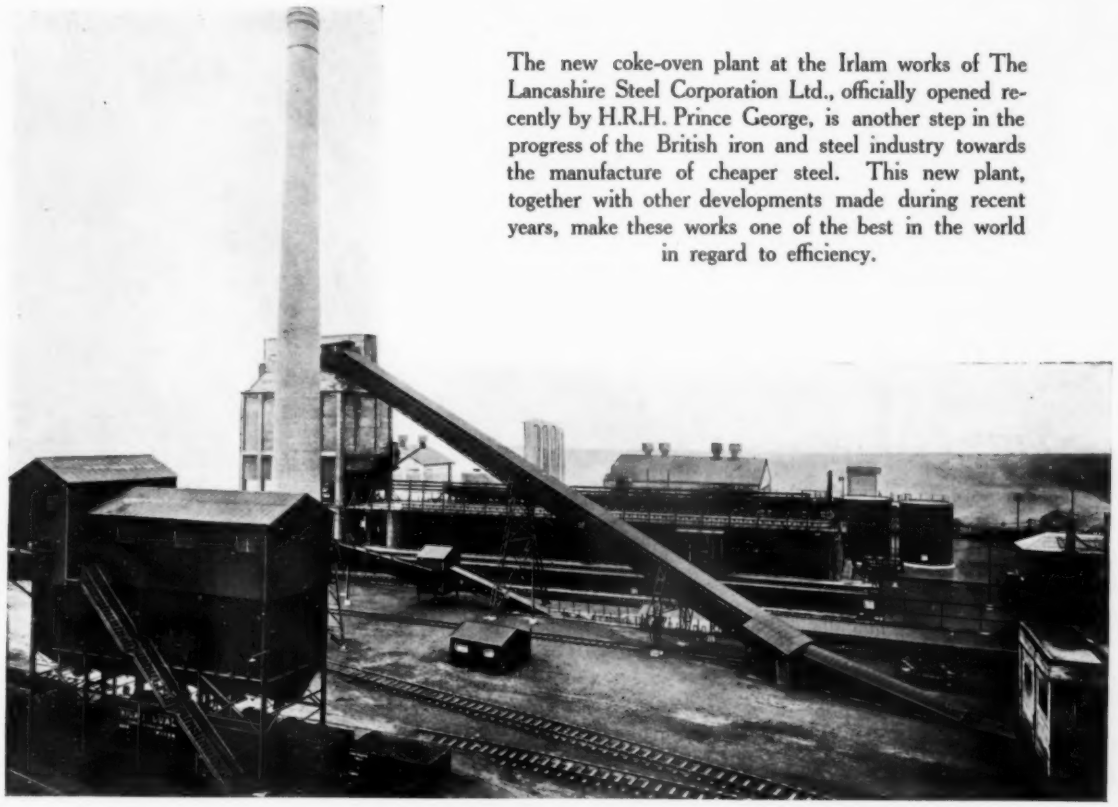
METALLURGIA

THE BRITISH JOURNAL OF METALS.

MAY, 1933. VOL. VIII., No. 43.

CHEAPER STEEL DEVELOPMENTS

The new coke-oven plant at the Irlam works of The Lancashire Steel Corporation Ltd., officially opened recently by H.R.H. Prince George, is another step in the progress of the British iron and steel industry towards the manufacture of cheaper steel. This new plant, together with other developments made during recent years, make these works one of the best in the world in regard to efficiency.



General view of "Becker" coke-oven installation, showing oven battery, coke screening plant and by-product plant.

IT is common knowledge that the Government was prepared to grant provisional protection to the iron and steel industry on the understanding that the opportunity would be taken by those engaged in the industry to formulate and carry through an approved scheme for its reorganisation and re-equipment. But extensive developments had been effected before a duty on imported iron and steel had been instituted. They have been carried out under great difficulties and frequently with little capital expenditure, and though the full results are not possible until plants are operating nearer to full capacity there is ample evidence that many British plants are able to produce as efficiently and as economically as the most modern plants abroad.

Reorganisation has been in progress for many years, and there has been much unification of forces to meet the adverse conditions in the industry. The producers of iron and steel in Lancashire, for instance, realised the advantages possible by amalgamating their interests and modernising and centralising their equipment in order to produce more efficiently and economically. This led to the formation of the Lancashire Steel Corporation, Ltd., over three years ago, and a considerable sum of money has been spent in installing modern machinery at their works at Irlam. One of the most important of these installations is the centralised plant for the production of coke required in the blast-furnaces. This, together with other installations and economies which have been effected in other parts of the works, has revealed the wisdom and justified the courage of the directors in seeking greater efficiency and economy.

In these works the coke-ovens, blast-furnaces, open-hearth plant, and rolling mills are arranged on one site, steel thus being produced from the raw materials to the finished article, and full use is made of the heat in the surplus gases from the coke-ovens and blast-furnaces. From a fuel efficiency point of view, this plant is of outstanding interest. This has resulted from the installation of a battery of 51 Becker ovens, coal handling, washing, blending, and crushing plant, coke screening and handling plant, and by-product recovery plant, including benzol plant for the production of motor fuel.

The raw coal, much of which is supplied by the Wigan Coal Corporation, Ltd., is received in wagons which pass along the plant sidings to a wagon tippler for discharge into the coal track hopper. From the hopper the coal is delivered by a belt conveyer to the raw coal bunkers, from which it is fed to the coal washery through a de-dusting plant. The coal washery is of the automatic Baum type, having a capacity of 175 tons per hour, and is fully equipped with dewatering sieves to reduce the moisture content of the coal.

The washed coal is finally delivered to the blending

bunkers, where provision is also made for the further draining of the coals before discharge over revolving tables to regulate the proportion of each class. The mixture of dust originally extracted from the raw coal and the recovered slurry is at the same time added to the blended washed coals in suitable proportion, and the mixture is delivered to the crushing plant, where it is reduced to a finely pulverised state. This is then conveyed by belts to the oven bunker, where accommodation is provided for 2,000 tons of coal.

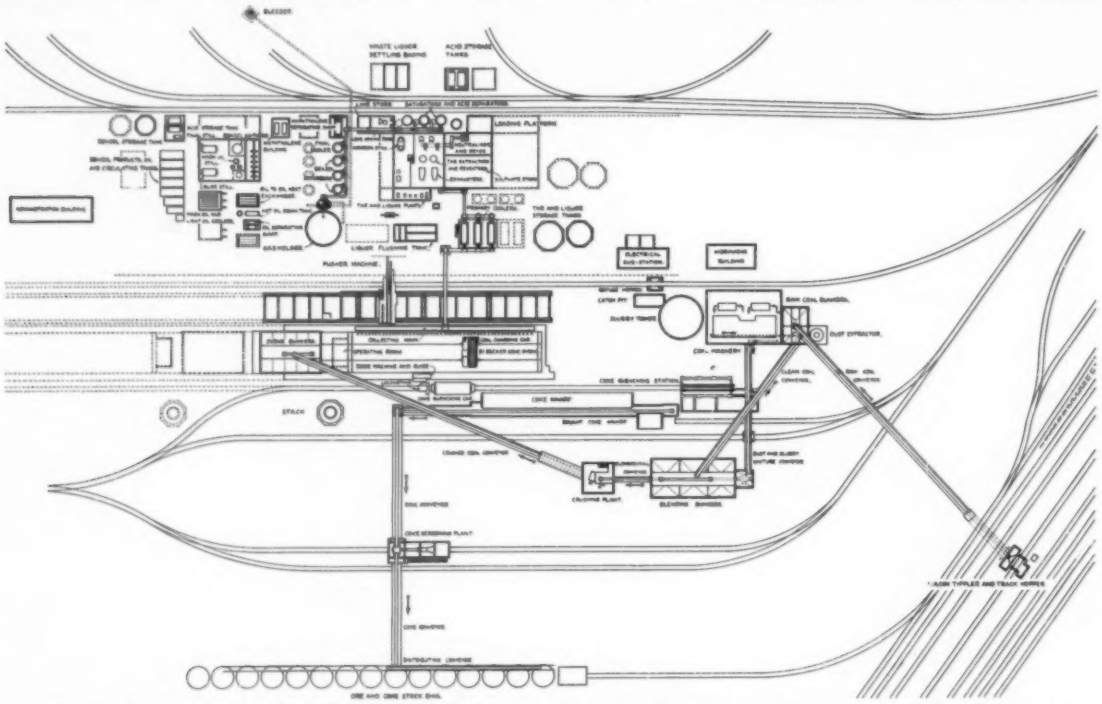
The Oven Battery and Heating System.

The ovens are of the Becker regenerative combination type constructed by the Woodall-Duckham Vertical Retort and Oven Construction Co. (1920), Ltd., each being 40 ft. 8 in. long between doors, 13 ft. high, and having an average width of 16 in. With a holding capacity of 651 cub. ft. each, the ovens are capable of producing 5,000 tons of coke per week. The oven brickwork from the pad upwards is constructed entirely of first quality silica, excepting only the filling in the regenerators and the end walls adjacent to the pinion walls. The oven jambs, regenerator facings, and oven tops are insulated, the latter having a finish of paving bricks. The pinion walls at each end of the battery are constructed in concrete and provided with substantial wing walls.

The heating system of this type of oven consists of a series of vertical flues on each side of each oven, with two regenerators built under each series of vertical flues. In this instance the ovens are designed so that they can be heated with either coke-oven or blast-furnace gas. When employing coke-oven gas both regenerators are used for preheating the air for combustion. The coke-oven gas is delivered through a horizontal gas conduit carried in the brickwork between the top of the regenerators and the bottom of the vertical flues. From these conduits the gas passes by means of a calibrated nozzle and vertical duct into the bottom of each vertical flue, where it mixes with the preheated air.

The air and gas come together with stream-line effect, and the combustion zone is evenly distributed throughout the height of the vertical flues. The products of combustion are then collected from the top of each group of four or five vertical flues and are carried over the top of the oven by means of cross-over flues. There are six cross-over flues to each alternate oven, none being required for the intermediate ovens.

From these flues the waste gases are distributed into an equivalent number of vertical flues on the other side of the oven. They then travel down these flues into the two generators immediately below, through which they pass to the waste gas flues, giving up heat to the chequer filling in transit. Upon reversal, which is automatically controlled, the air travels up the regenerators, through which waste gas has previously passed, meets the coke-oven gas and combustion takes place upwards ; the products of combustion travel through the cross-over flues, and down the flues up which the burning gas has previously travelled, finally passing out through the corresponding regenerators.



General layout of "Becker" coke-oven installation, coal washing, blending and handling plant, coke handling and screening plant, and by-product plant.

This arrangement of heating ensures that the travel of gases throughout the system is short and unidirectional, and, consequently, there is a low-pressure differential and absence of leakage. The velocity of gases is slow and uniform, so that excellent regulation can easily be obtained.

The reversing valves are designed so that with the provision of blast-furnace gas mains, any or all of the ovens can be heated by means of blast-furnace gas. In this case air will travel up one of the two regenerators and gas up the other. Both the air and the gas will enter the bottom of their respective regenerators from both ends of the oven at the same time. After passing through in an upward direction and absorbing heat from the chequer filling in transit, they will leave the top of the regenerator and enter the bottom of the vertical flues. From this point onwards the flow of gases would be the same as when coke-oven gas is used.

The reversing machine is placed in an operating and instrument room at the end of the battery, the movements of which are controlled by an electric clock. Should this clock fail to operate the mechanism at the predetermined time, within one minute an adjustable water-clock causes a steam siren to blow. A hand-operated decarbonising machine is also situated in the operating room ; this actuates the mechanism which raises the air lids on the gas guns to remove carbon deposits. All the gas and steam meters for the plant as a whole are centralised in this room.

General view of coal washery, showing slurry tower.

View of blending bunkers, showing also coke-quenching station and bought coke wharf.

De-Dusting and Coal Washery.

The whole of the raw slacks are delivered to the plant by means of 10-ton to 15-ton wagons in two groups—namely, "low sulphur" and "high sulphur" slacks, which are handled, stored, and washed separately. There are approximately eight different slacks in each of the two groups, and the total daily raw slack at the present time consists of approximately 70 per cent. of Lancashire and 30 per cent. of Yorkshire.

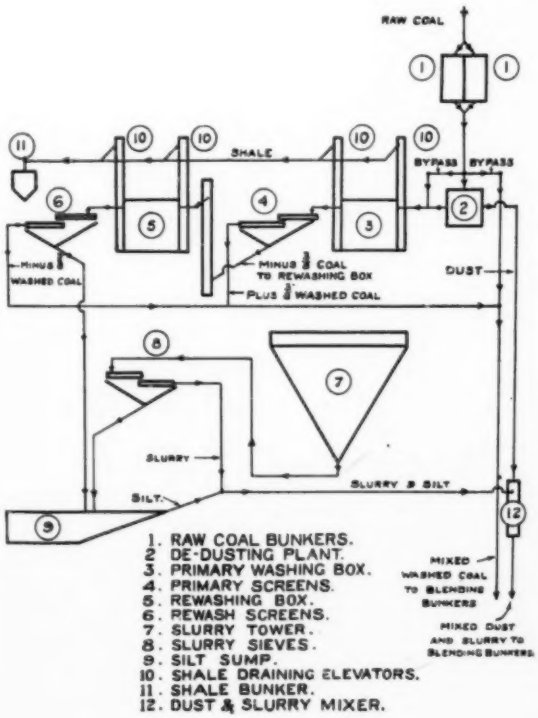
Two bunkers, each of 250 tons capacity, are provided at the washery for the raw slack storage. One bunker is allocated to each raw slack group, one being filled while the other is being emptied, thus ensuring continuous operation in the washery. Each bunker is provided with a hand-operated slide-gate and indicator for regulating the discharge to the feeding and distributing conveyer which delivers the raw slack in equal proportions to the four aspirator units in the de-dusting plant. The de-dusting plant is of the "Birtley" type, and is arranged for aspiration at $\frac{1}{60}$ in.

The raw coal discharged from the feeding conveyer is delivered by means of rotary feeders and special distributing feed chutes into the four sections of the aspirator, and is drawn into the aspirating chamber by means of the primary atmospheric air. The secondary air is drawn in through the lower secondary air ports and rises through the free falling coal, removing the dust, which is carried forward in the air stream, the coarsest particles being precipitated in an expansion chamber and the remainder carried forward to a dust extractor. The medium coarse particles are precipitated directly in a cyclone and only the finest dust is carried forward for extraction in a bag filter.

The washing boxes, two of which are provided, are of the Baum compressed air type, and are provided with Norton-Harty completely automatic shale extractor gates. The de-dusted raw slack is delivered to the inlet end of the primary box via the raw coal trough in which the slack is sluiced by means of a stream of water. The coal product from this box is screened over a $\frac{3}{8}$ in. jigging dewatering screen, and the coal, etc., below $\frac{3}{8}$ in. passing through the screen is re-elevated and delivered to the rewashing box which delivers final clean coal below $\frac{3}{8}$ in. and final shale below $\frac{3}{8}$ in.

The final washed coal from the primary and rewashing boxes is dewatered over fixed sieves and double-balanced jigging dewatering sieves. The washed coal, together with the washing water, is conveyed by means of troughs from the boxes to the fixed sieves which partly dewater the coal and distribute it to the feed end of the jigging sieves, which further dewater the coal and feed it to the washed coal-mixing belt.

The concentrated slurry discharged by gravity from the bottom of the slurry tower is fed to two jigging sieves, where it is dewatered and fed to the screw type slurry and dust-mixer. The whole of the plant is driven by means of electric motors, and the starters for the whole of the de-dusting, washing and dewatering apparatus are grouped together at a convenient point on the washer floor and are located in the correct order for starting.



View of oven top, showing oven storage bunker, coal charging car and gas ascension pipes.

Coke side of battery, showing coke wharf, combined coke guide, and door machine and coke quenching car with electric locomotive.

Coal Blending and Crushing.

Coal leaving the washery is delivered by belt conveyers into the blending bunkers. These consist of six separate compartments with a total capacity of 2,000 tons, whilst a further hopper is provided for the mixture of dust and slurry. The main bunkers are designed both for blending and drainage purposes. Below each bunker a revolving table is arranged in order to regulate the exact rate of discharge on to a common receiving conveyer carrying the coals to the crushing plant, consisting of two hammer-mill type machines, one machine being normally in operation, whilst the other serves as a 100% standby. From the hammer mills a further belt conveyer delivers the pulverised coal, now intimately mixed, to the ovens bunker, into which it is discharged by means of a shuttle belt conveyer.

Oven Charging and Discharging.

The coal for the ovens is stored in a reinforced-concrete bunker, consisting of twenty hoppers, having a capacity of 2,000 tons of washed crushed coal. Each of the hoppers has a discharge gate hand operated from a platform beneath the bunker. An electrically propelled coal-charging rail-car, fitted with four steel hoppers, each fitted with an electrically operated mechanical stirrer and an adjustable measuring device, runs along the top of the battery. Each hopper is also provided with a cast-iron drop sleeve for directing the coal into the ovens, and a steel sliding gate. The coal in the car is weighed before charging, and a ticket-punching device records the weights.

When carbonisation of the coal charge is complete, the coke is discharged by the pusher machine into a coke-quenching car. The pusher machine, which runs on rails

Pusher side of battery, showing pusher machine, gas-collecting main and suction main.

along the full length of the battery, carries a ram which is built up of structural steel with a cast-steel head. It also carries a rope-driven leveller bar and a door extractor with slewing action, designed to handle the self-sealing doors. The machine, pusher ram, leveller bar, and door extractor are all operated by separate electric motors. A spare coke ram and leveller bar are kept at a ram-changing station situated below the coal-bin.

The coke is received in a coke-quenching car, which is hauled by an electric locomotive to a quenching station of the recirculating type, where it is sprayed with a predetermined quantity of water. After quenching the coke is discharged on to an inclined coke wharf 160 ft. long to cool, from which it is fed through hand-operated finger-type regulating gates on to a 36-in. belt conveyer and subsequently carried by a conveying system to a double-deck Gyrex screen capable of separating all the coke above 1½ in. in size and screening the remainder into 1½ in. to 1 in. and 1 in. to 0 sizes. The coke over 1½ in. is fed on to a belt conveyer, which delivers it on to a shuttle belt for distribution into the blast-furnace bins.

Gas-Collecting System.

The crude gas leaves the ovens through ascension pipes and passes into a steel gas-collecting main. One ascension pipe lined with special insulating material is provided for each oven, and each pipe is fitted with a spray for liquor flushing. Sprays are also provided in the main at alternate ovens. The collecting main is equipped at each end with a liquor-sealed bleeder. A gas-pressure regulator, consisting of a butterfly valve in the suction main controlled by an "Askania" governor, maintains a constant pressure in the gas-collecting main.

The gas passes from the ovens to the primary coolers, where the tar and ammoniacal liquor are condensed. From the primary coolers the cooled gas is passed by the exhausters to two combined tar extractors and reheaters. These are of the "P. and A." type, with fixed circular bells, and the reheaters consist of steam radiator sections, arranged in the bottom of each combined unit.

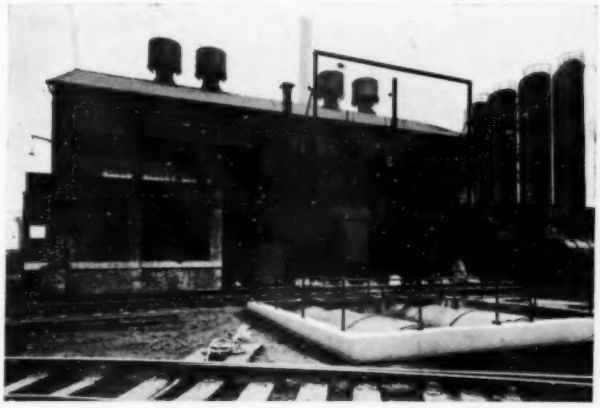
Two turbo exhausters are provided, each of which is capable of passing all the gas produced at the ovens and delivering it against a normal pressure of 2½ lb. when running at a speed of about 4,000 r.p.m. Each exhauster is direct-coupled to a steam turbine operating with steam at 120 lb. per sq. in., and exhausting against a back pressure of 15 lb. per sq. in.

By-Product System.

From the combined tar extractors and reheaters the gas enters the ammonia saturators containing a sulphuric acid bath through which the gas bubbles and passed out through separators, where any traces of sulphuric acid are removed. The wet sulphate produced is ejected into one of two drain tables and subsequently dried in centrifuges. These are of the suspended self-balancing type, and are driven by steam-engines. From these machines the sulphate is fed by a belt conveyer into a "Wilton" drier, which both dries and neutralises the salt. The dry neutral sulphate is discharged into an elevator, feeding into a bagging hopper of 25 cwt. capacity.

The ammonia condensate from the primary coolers is distilled in a still, having a capacity of 2,400 gals. of ammonia liquor per hour. The free section contains six trays, and the fixed section nine. The ammonia so produced passes into the gas stream immediately before it enters the saturators.

Ammonia liquor from the liquor compartment of the flushing and separating tank is pumped from the storage tank to the ammonia still. Waste liquor from the still is received in a waste liquor settling basin and the decanted liquor is suitably disposed of. The tar from the tar compartment of the liquor flushing and separating tank is delivered into a storage tank and drainage from the exhausters and tar extractors, and overflows from the tar



View of by-product building, showing ammonia saturators and acid separators, sulphate-loading platform and acid tanks.

and ammonia liquor storage tanks, are received in a condensate drain pit, whence they are transferred into the tar and liquor storage tank by means of a pump float controlled by the level of the tar in the drain pit.

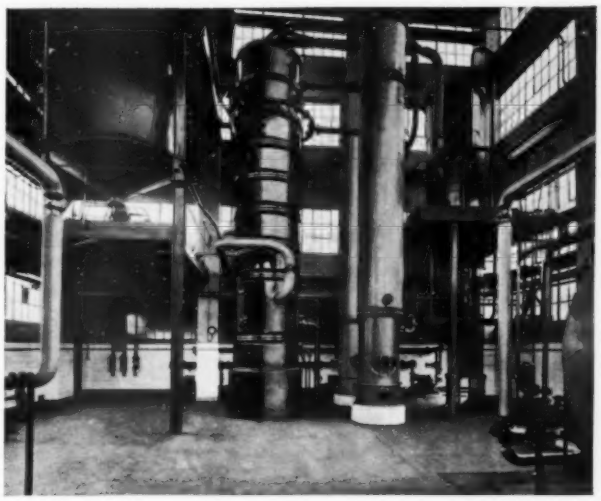
A lead-lined liquor tank having a capacity of 4,000 gals., receives the acid drip in the gas main after the separators, and acts as a reservoir for emptying the saturators. The tank is located at yard level, and mother liquor is delivered from this tank to the saturators by means of a bronze acid ejector. A smaller mother liquor tank receives drainage from the floors and from acid drips, which is similarly ejected to the larger tank.

After leaving the saturators and acid separators, the gas passes through a hurdle type final cooler, where the naphthalene is removed. After final cooling the gas is debenzolised in three tower scrubbers. As the gas passes up through these towers it meets a descending stream of wash oil, which absorbs the crude benzol. This wash oil, enriched with benzol, is delivered into a specially designed distilling apparatus provided with the necessary heat exchangers, condensers, and coolers. The benzol rectification plant comprises two stills with columns, dephlegmators and coolers, and agitator, naphthalene pans, and suitable tanks for intermediate and final products.

After leaving the benzol scrubbers the gas passes through the total gas meter before entering a fuel gas-holder of 20,000 cub. ft. capacity. This is designed to maintain a constant presure at the battery, and to serve as a reservoir for gas during reversal periods. The gas connection from this holder delivers into a header from which separate lines are carried to the battery, the bleeder, and to the steel plant. The battery line, which runs below ground, supplies gas to the riser pipe at the end of the battery. The surplus and bleeder lines are each equipped with automatic valves regulated by the position of the gas-holder.

This coke-oven plant does not completely meet the needs of these works and a special handling plant has been installed capable of dealing with coke bought from outside sources. An additional battery of ovens is, however, contemplated, and a substantial revival of trade would assist in a decision to proceed further with this project so that the works would be self-sustaining not only in regard to coke for the blast-furnaces, but in regard to the supply of all the gas needed for heat in processing the products.

Interior view of benzol building, showing wash-oil still, vapour to oil heat exchanger, final heaters and, in background, benzole pumps.



BRITISH STANDARD INDUSTRIAL SIEVES AND SCREENS.

A British Standard Specification has just been issued for square-mesh woven wire and round-hole perforated plate sieving materials for industrial purposes. This specification provides for the more commonly used forms of woven wire and perforated plate, and has a wide industrial application, covering as it does the fine woven wire sieving material used in biscuit making, gold mining, brewing, etc., up to the very heavy forms of perforated plate used in the coal-mining and quarrying industries.

So far as woven wire is concerned, it has been found necessary, to meet the needs of industry, to include two series of woven wire, which are characterised by—

(1) Clear mesh sieves, in which the size of the aperture is expressed in inches or fractions of an inch.

(2) The number of meshes per linear inch, this series containing sieves ranging from 300 meshes to the inch down to 4 meshes to the inch.

It has been found practicable to standardise perforated plate other than those having round holes staggered at 60°. Two series of perforated plates have been provided, a heavy series with holes from 3 in. to $\frac{1}{16}$ in. diameter, and a light series with holes from 1 in. to 0·029 in. diameter.

In consequence of the great variety of lengths and widths used in industry, it has not been found practicable to standardise overall dimensions of woven wire or perforated plates.

Attention is drawn, however, to the fact that woven wire is generally stocked in widths of 24 in. and 36 in., with a selvedge on both sides, and in certain meshes in widths of 21 in., 22 in., and 40½ in. for supply to particular industries.

The material used in the manufacture of woven wire depends on the purpose for which it is required. It cannot, therefore, be standardised, but is normally stocked by makers as follows :—

Steel	Up to	90	mesh
Copper	,,	100	,,
Brass	,,	200	,,
Phosphor bronze	,,	300	,,

It has been found impracticable at the present stage to lay down tolerances for the standard sizes of apertures either for woven wire or perforated plate. The co-operation of both manufacturers and users is invited in this matter, so that the revision of the specification in this direction may be possible after one or two years' experience has been gained. Any information as to rapid methods of measuring the aperture size of woven wire cloth, and as to results obtained upon material supplied under this specification should be sent to the offices of the Institution.

Copies of this specification (B.S.S. No. 481-1933) can be obtained from the British Standards Institution, Publications Department, 28, Victoria Street, London, S.W. 1, price 2s. 2d. post free.

Hardness Fluctuations in Hardened Steel.

Curious discrepancies have been found in the hardness of specimens of nitrided steel which apparently confirm the work of Herbert, who has investigated hardness fluctuations.

IN an article in *Stahl und Eisen* (April 6, 1933) Dr. Otto Hengstenberg describes a series of experiments on hardness fluctuations observed during the ageing of various hard steels. It appears that in measuring the hardness of taper-ground specimens of nitrided steel curious discrepancies were noted between hardness measurements made with an intervening interval of a few days. As these could not be accounted for either by personal errors or local variations, an elaborate investigation was undertaken to find whether and in what manner the hardness of nitrided steel varied

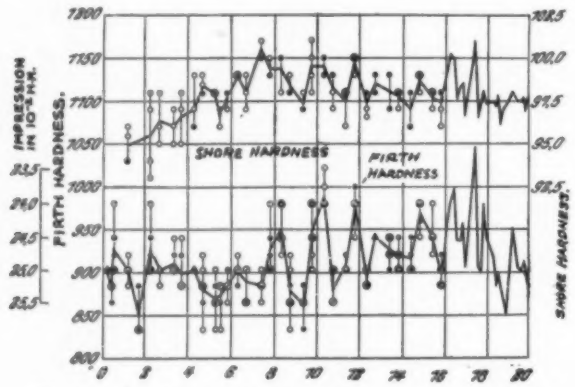


Fig. 1.—Simultaneous hardness measurements by different Systems on specimen of Nitralloy steel, nitrified 100 hours at 500°C

over a period of time. In these experiments the specimens were not taper-ground, but 0·1 mm. was removed evenly from the surface, which was then divided into eight areas, in each of which hardness tests were made with several different instruments and their averages compared. Fig. 1 shows the hardness variations over a period of 20 days, as shown by the Firth instrument and the Shore scleroscope respectively.

Altogether five systems of hardness testing were used in these experiments :—

1. The Firth diamond pyramid.
2. The Rockwell, with 62·5 kg. load.
3. The Rockwell initial load, 10 kg., was applied and removed, the diameter of the impression being measured.
4. The Rockwell initial load was applied and dial reading taken.
5. The Shore scleroscope.

It will be noticed that the first three were tests of what has been called "plastic hardness," the criterion being the plastic or permanent deformation remaining after removal of the load. In the last two tests, measurement was made under load, or under conditions which would be affected by elastic changes in the specimen.

The significance of this distinction will be seen in Fig. 1 where the scleroscope showed a progressive increase of (elastic) hardness during the first seven days, while the Firth gave no indication of an increase of (plastic) hardness. In the later period there was a striking similarity between the fluctuations shown by the two instruments.

Further experiments were made with quench-hardened steels containing 1·02 and 0·79 carbon respectively. Significant hardness fluctuations were found in every case, not only in the freshly hardened specimens, but actually in some which had been hardened nine years previously and the fluctuations were of considerable magnitude, extreme variations of approximately 200 diamond hardness numbers being found.

In order to reduce further the possible influence of personal error and of local hardness variations, a specimen of steel containing 1·02 C., quenched at 800° C., was observed over a period of 30 hours, 16 hardness tests being made with each of two testing instruments every 30 mins. The respective tests were made by two operators, the averages taken, and the measurements independently checked. The results shown in Fig. 2 confirm the occurrence of hardness fluctuations over the whole period.

Reference is made to the work of E. G. Herbert, who found periodic fluctuations of hardness in tool steel and other metals, during an ageing period of several hours after rotary magnetic treatment, and also after quenching, cold working, and heat treatment at low temperatures. The present investigation must be held to confirm the occurrence of hardness fluctuations, but there are also notable differences to be observed. While Herbert's experiments displayed periodic fluctuations following immediately on a severe disturbance—magnetic, thermal, or mechanical,—and damping out in the course of several hours, the present experiments gave no evidence of regular periodicity, and so far from damping out, the fluctuations were found to have persisted with undiminished intensity over long periods, amounting in some cases to years. The evidence thus suggested a fluctuating or recurring source of disturbance, taking effect while the experiments were in progress.

Attempts were made to discover a possible disturbing influence, by noting variations of room temperature, by seeking possible cyclical variations in the springs used in the Firth and Rockwell machines, and even by noting

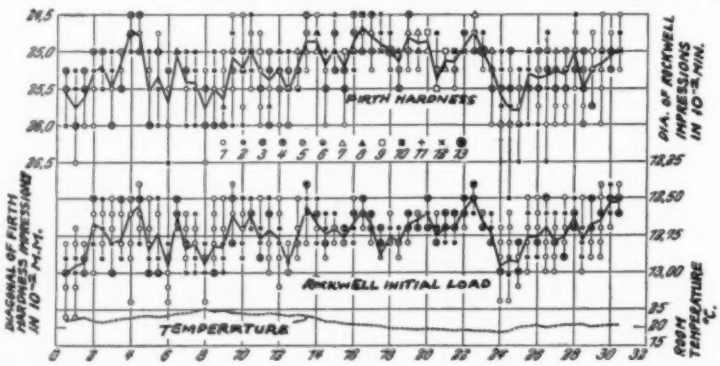

FIRTH HARDNESS
ROCKWELL INITIAL LOAD
TEMPERATURE
DIA. OF ROCKWELL IMPRESSIONS IN 10 m.m.
DIAGONAL OF FIRTH HARDNESS IMPRESSIONS IN 10 m.m.
ROOM TEMPERATURE °C.

Fig. 2.—Hardness changes in steel, 1.02 C, 0.23 Si, 0.21 Mn, quenched in water from 500°C. Hardness measured by Firth, and Rockwell, initial load 10 Kg.

climatic conditions (a thunderstorm is mentioned in this connection), but no adequate explanation appears to have been discovered. The author rightly concludes that differences in the results of such measurements must be reckoned with, even when they are made by experienced persons and with the greatest care.

METALLURGIA

The British Journal of Metals

★ The source of all matter extracted from this Journal must be duly acknowledged; it is copyright. ★

Contributions suitable for the editorial pages are invited. Photographs and drawings suitable for reproduction are welcome. Contributions are paid for at the usual rates.

PRINCIPAL CONTENTS IN THIS ISSUE:

	Page
Cheaper Steel Developments *The new coke-oven plant at the Irlam Works of the Lancashire Steel Corporation is another step in the progress of the British iron and steel industry towards the manufacture of cheaper steel.*	1–5
British Standard Industrial Sieves and Screens	5
Hardness Fluctuations in Hardened Steel	6
Fuel Economy and Efficiency in the Iron and Steel Industry	8
Trade Revival Possibilities	9
Fuel Oil Import Duty	9
Steel Castings *First report of Research Committee*	10
Forging and Rolling Temperatures of Steels. Part II. By J. H. G. Monypenny, F.Inst.P. *In this article the author deals with the forging and rolling temperatures of alloy steels of various types.*	11–14
Strong Light Alloys of To-day. By Leslie Aitchison, D.Met., B.Sc., F.I.C. *During recent years considerable activity has been witnessed in the field of non-ferrous alloys based upon aluminium or magnesium. In this article the situation is reviewed from the standpoint of a consideration of their ruling properties, particularly to those materials which are available and are employed in the wrought condition.*	15–17
Reviews of Current Literature *Designing for Arc Welding.* *Patents Explained.*	18
The Iron and Steel Institute *The annual general meeting held in London.*	19–22
The Phenomena of Quenching and Tempering in Alloys. By Professor Albert Portevin *Two principal means are used to improve the properties of metals and to modify them in a desired direction—the preparation of alloys and the use of heat-treatments. The latter means was discussed by the author in the May lecture of the Institute of Metals.*	23–24
A New Lead Alloy	24
Nitricastiron: Cast Iron Suitable for Hardening by the Nitrogen Hardening Process. By J. E. Hurst *In comparison with ordinary cast-iron nitricastiron shows a higher strength, a higher modulus of elasticity, a lower permanent set value, and a greater intrinsic hardness, and, as its properties become more widely known, its uses will extend.*	25–27
Measurement of Large Volumes of Gas *A curved tube manometer.*	27
Reports on Cold Working of Steel and Other Ferrous Metals	28
Recent Development in Tools and Equipment *New Aluminium Strip Rolling Plant.* *High Speed Foundry Grinding.* *Bearings that Lubricate Automatically.*	29–30
Protecting Iron and Steel Against Corrosion *Many methods are adopted to afford steel protection against corrosion, in this article the most commonly used methods are discussed.*	31–32
A New Oil-Fired Sand Dryer	32
Sulphate Roasting of Copper Ores	33
The Chemistry of Indium	33
Metal Prices	34

Subscription Rates throughout the World - - 24/- per annum, Post free.

Published Monthly by the Proprietors, THE KENNEDY PRESS LIMITED, at 21, Albion Street, Gaythorn, Manchester.

Telegrams: "Kenpred," Manchester. *Telephone: Central 0098.*

METALLURGIA

THE BRITISH JOURNAL OF METALS.

FUEL ECONOMY AND EFFICIENCY IN THE IRON AND STEEL INDUSTRY.

THE eminence of the British iron and steel industry in former years was built up on cheap fuel conditions when no economic advantage could be gained by the expense involved on plants necessary to save fuel. Market requirements for the products of the industry varied so much that mass production of standard materials could only be adopted to a very limited extent; in consequence it was not easy to reproduce results of fuel efficiency per ton of product such as were obtained at foreign works operating on mass production lines. Because of this and other factors the dear fuel period which followed the war found this country at a distinct disadvantage. A reconsideration of the position was essential, but obtaining capital for necessary plant proved a difficulty.

This difficulty was not experienced to anything like the same degree on the Continent. Many plants in these countries were entirely destroyed during the war and complete rebuilding was necessary, while the inflation policy adopted in certain countries reduced the charges on existing plants to negligible proportions and made it easier to obtain new equipment. Lower wages in these countries together with depreciating currencies stimulated their exports and enabled plants to operate at relatively high capacity, resulting in high fuel and production efficiency. In Germany, for instance, the deflation in currency enabled industry to obtain cheap labour and materials, and, by borrowing a large amount of capital abroad, she was able to conform to the requirements of the Versailles Treaty and reorganise her industries to meet peace time conditions.

In this country we were under no such compulsion and conversion of plant and factories to normal conditions proceeded in a more haphazard way. With the exception of a few outstanding examples, complete reorganisation to the same extent as on the Continent was not attempted, with the result that in a restricted market British manufacturers suffered. Great Britain faced her responsibilities abroad too readily, and failed to give that attention to domestic problems which were of equal importance. The stabilisation of the pound imposed a severe strain on the financial structure, which prevented much reconstruction or new installations of plant. It is not surprising, therefore, that the British iron and steel industry, working with high labour costs, heavy transport charges, and heavy taxation, found its competitive power reduced to such an extent that its productive efficiency was seriously impaired.

That Great Britain has lagged behind her foreign competitors in the scientific utilisation of fuel in the iron and steel industries is largely due to these factors. While it was realised that fuel consumption in certain producing districts in this country was high in comparison with practice on the Continent, no real attempt to investigate the reasons was made until 1923. Since that time, however, there has been slow but steady progress, with the result that the amount of fuel per ton of product has been gradually reduced.

One of the most important developments arising from the need for high fuel efficiency was the institution of fuel control departments in many works. These were instituted to investigate fuel consumption in various stages of production and by control, improvement of plant, and operating efficiency, and where possible, by installing suitable equipment, were required to improve fuel technique. In view of the general uneconomic production resulting from the obsolescence of much plant following the war, attention was concentrated on coke-oven plants. In this country these plants were small, and they produced a wide variety of cokes. Steady improvement in coke quality and uniformity has since been made in the various producing districts. This has been secured by giving the coal a suitable preliminary treatment and by making larger individual coking units.

In both these directions of development problems have been encountered which necessitated considerable research. Coke quality of course is only one of the factors in the operation of the blast-furnace that has involved separate study, but fuel technology has developed so much during recent years that the gases obtained in manufacturing as well as in using the coke are being employed to effect economies in the manufacture of steel and in subsequent processing operations. In many cases remarkable success has been achieved, and many British works are operating on a thermal efficiency not surpassed in any other producing country. In these instances no fuel is used other than the coal charged in coke ovens, and after the production of pig iron the whole of the subsequent processes in steel-making are met by the use of coke-oven and blast-furnace gases.

Progress to this high standard has only been achieved in a few works, but the delay in the more general application of this form of modernisation in this country has at least had one advantage ; it has afforded iron and steel manufacturers the opportunity of watching the trend of developments and of determining, after long periods of operation, what developments contribute most to economical operation. Probably the most important factor arising from these developments is the importance of uniform heat on the successful operation of the coke-oven. This does not mean the application of a uniform temperature to the oven, but a temperature that will secure as near as possible uniform heat in the oven. In some instances there has been a tendency for excessive heat at the top of the oven, due probably to differences in coal shrinkage from different grades of coal ; experience has shown this to be detrimental to successful operation, which emphasises the necessity of controlling the heat applied.

The trend of progress towards the manufacture of cheaper steel in this country is given a further impetus by the opening of the new coke-oven plant at the Irlam works of the Lancashire Steel Corporation, Ltd. A description of this plant is given elsewhere in this issue, from which will be obtained some idea of the developments which are being effected by making full use of fuel. Although this plant does not completely supply all the heating medium necessary in these works, it contributes in making them of outstanding interest with regard to high fuel efficiency. The fullest advantage is taken of waste heat recovery, and firing can be effected with producer, coke-oven, or blast-furnace gas, or a mixture of these. A continuation of this policy by the British iron and steel industry as a whole will rapidly place it in a position of competence with its competitors abroad and restore to it the position of eminence it formerly occupied.

TRADE REVIVAL POSSIBILITIES.

MANY people competent to judge are of the opinion that a trade revival is in sight. There is much to encourage this view; it will have been noted, for instance, that the unemployment figures again show a decline. This is the third month in succession that unemployment figures have shown a decline. Nearly a quarter of a million more people were employed at the end of last month than at the end of January of this year; it is not surprising, therefore, that many people view this change as an omen pointing towards recovery.

Under normal conditions more people are employed during the early months of the year, but trade has not been normal for some years, and during the early months of the last three years diminishing unemployment was not maintained to the extent that we had grown accustomed to. This year, however, the decline in unemployment from January to April was nearly three times greater than last year. There is, therefore, a certain justification for regarding this as a real improvement rather than one arising from the changing season. It is noteworthy that engineering is one of the industries responsible for the decline in unemployment. Probably a contributory cause of this improvement has been the gradual rise that has taken place in the prices of most raw materials.

Rising prices have created greater confidence, and business men are feeling more hopeful. Some industries at least are beginning to get back into their normal condition of activity, which seems to indicate that a turn in the trade tide has actually taken place. These signs of greater confidence are of great import, but the improvements in trade are relatively small, and are not yet sufficient to justify too much optimism. Trade conditions are so delicate and liable to fluctuations that the improvement could easily be reversed by a new wave of depression, as did that following the Lausanne Conference.

The prospects likely to emanate from the World Economic Conference are probably one cause of a more hopeful outlook. With its success we shall gradually see recovery of prices and production in all countries, but, should it prove a failure, the depression which will result will tend to swamp the existing improvement. This economic conference, consisting of representatives from sixty-six nations, will formally meet on June 12. Actually, the work has started, for it has been announced that the eight nations represented on the organising committee had agreed to put a tariff truce into operation at once. Agreement in advance by Belgium, Britain, France, Germany, Italy, Japan, Norway, and the United States is an indication of the possibilities at the Conference. Nothing will assist trade recovery so much as a reduction in tariffs and trade barriers, and it is important that agreement has been reached to prevent any one increasing tariffs in order to effect an apparent advantage.

Apparently the Conference proper will not consider war debts, a question of primary importance to Great Britain: it is to be discussed separately in the intervals of the general Conference. It is questionable, therefore, whether an amicable arrangement can be made before June 15, when the next instalment of the debt falls due. If it were possible for Mr. Roosevelt to grant a moratorium for a reasonable time so that negotiation could proceed without undue haste, the position would be simplified, but Congress apparently does not favour this course. We are hopeful that this question will be settled, because the United States are as anxious as this country to remove trade obstacles.

Decisions at this Conference will obviously be a matter of compromise, but if suitable results are achieved that favour an adjustment of the present monetary exchange troubles the flow of world trade will be given a tremendous impetus and the improvement now shown in our trade may well be the forerunner of complete recovery. We are in agreement with Sir Francis Goodenough, however, that such a revival will come slowly, and, to benefit fully, all countries should first get rid of the present intense economic nationalism and return to international trading.

FUEL OIL IMPORT DUTY.

IT is not surprising that protests against the proposed import duty on oil fuel are reaching the Chancellor of the Exchequer from business firms and organisations because fuel has always been recognised as one of the essential raw materials of industry. It is true that oil is only one of the fuels used, and that practically the whole of it is imported; because of this it is contended that, in many cases, other fuels, which are produced at home, will meet requirements: thus the industries involved in the production of these fuels will benefit, and to that extent will reduce unemployment.

Coal and coke are the basic fuels of industry, and they are undoubtedly the cheapest fuels on a heat unit basis, but in many industrial operations development has necessitated more accurate control of heat than can be obtained direct from these solid fuels, and in consequence oil and gas have been increasingly employed to meet this special need. Each of these fuels, together with electricity, has its own particular field of usefulness, although cost has an important influence on its selection. It should, however, be borne in mind that the cost should not be calculated on the amount of heat produced, but rather on the character and quality of the work done.

The suggested import duty is 1d. per gallon, which on small quantities means approximately 25% on the cost to the consumer; sold in larger quantities, however, the present cost to the consumer may be 60s. or less per ton of about 245 gals. Thus the cost with the import duty would be advanced 33⅓% or more to large consumers. To many industries this additional expenditure will present difficulties at a time when trade shows signs of a revival, and it is probable that some of the developments that have resulted from the use of oil-fuel and the effect of so considerable an increase has been overlooked. Probably the greatest development has been in connection with the Diesel engine, and considerable progress has been made in this country in providing more efficient and more economical transport facilities. British engineers, during the severe trade depression, have been forced by keen foreign competition to develop internal combustion engines, and their increasing application to marine propulsion, rail and road transport is an indication of the progress made. The great increase in cost of oil-fuel due to the proposed import duty will negative the economical advantages obtained from its use, and in regard to marine transport will place our shipowners at a disadvantage in comparison with their foreign competitors.

In the metallurgical trades, which consume about 275,000 tons of oil fuel per annum, the effect of such an import duty would be to cause certain consumers to use alternative fuels, but in other cases the change could not easily be done, and the consumer would need to bear the burden, in which case it would add to the cost of running the plant and reduce its competitive value.

Whether any additional employment would be provided is problematical because the gain experienced in one direction would tend to be compensated by a loss in the other, and the net result would be to increase the cost of production or transport. Such a result would tend to increase unemployment, because it would materially affect our competitive power in the world's markets. There would be distinct possibilities about an import duty of this character if oil from coal could be produced at a reasonably competitive price; then it would be a sound national proposition, but the production of oil from coal has not been developed to such an extent as to benefit from an import duty.

We are convinced that anything likely to raise the charge on industry, which is already excessively burdened, should be contested, and large and small users of oil fuel are justified in making representations so that the full significance of this proposed duty may be realised in time in order to effect modifications that are less likely to interfere with the distinct progress oil fuel has made possible.

STEEL CASTINGS.

FIRST REPORT OF RESEARCH COMMITTEE.

AN investigation on steel castings instituted with the object of improving their quality, with special reference to such defects as blow holes, porosity, flaws, cracks, pits, and non-metallic inclusions, was begun in the Research Department, Woolwich, in 1927, by the Department of Scientific and Industrial Research. As the work progressed, more attention was given to the industrial aspects, and the investigation became a general research into the improvement of steel castings from the point of view of the manufacturer and user. In October, 1930, a Committee was appointed to take complete control of the work, and its first report was presented at the recent annual general meeting of the Iron and Steel Institute.

In the first part of this report, the varieties and defects encountered in steel castings are discussed, and their influence is considered with special reference to the results of the examination of some typical castings, varying from about 1½ cwt. to 4 tons in weight made in the ordinary course of manufacture. In this way light was thrown on the characteristics and relative importance of defects such as blowholes, shrinkage cavities, and cracks, especially "hot cracks" or "pulls," etc., formed at temperatures little below the freezing point of the steel. Many castings of medium size were made to the same design under various conditions, each variable being defined as fully as possible, and although the conclusions drawn from these experiments apply primarily to the casting under consideration, they have a more general application. A higher standard of quality than that required for ordinary commercial castings is demanded for the highly stressed type of steel castings, and these have been kept in view during the progress of the work described in this report.

The main difficulties confronting the founder in the manufacture of steel castings are: natural difficulties, depending on the physical properties of fluid and solid steel; difficulties associated with design; and economic difficulties; and a discussion of these factors is based on the results of this work. The recognition of the requirements under these headings clears the way for the more quantitative application of scientific principles to the manufacture of castings.

Contraction on solidification and on subsequent cooling leaves cavities in the regions which solidify later than the surrounding parts, and also induces tension in parts which, on account of their form, are prevented by the mould from contracting freely. The founder endeavours to restrict various inevitable defects within the runners and risers, but often the design of the casting does not permit of this aim being realised, as the provision of completely adequate feeding heads would so increase the cost as to be prohibitive. In ordinary work defects in moderation do not reduce the serviceability of the casting and may be accepted, but in many castings a closer approach to soundness is necessary. In the experiments it is shown that, given adequate metal distribution, the attainment of soundness depended on the minimum weight of head, which amounted to at least 40% of the total metal cast. It also involved a minimum area of gates which precluded the use of long and narrow heads or of heads constricted at the lower end to facilitate removal.

In eliminating the cracking, no single factor appearing to be more effective than the filling of the mould as rapidly as possible, if necessary continuing to feed the heads as solidification occurred. The introduction into the mould of a body of metal as nearly as possible at a uniform temperature and adequately fed, appeared to provide conditions having the most pronounced effect; even so, additional strengthening by internal brackets was necessary to ensure absence of cracking at end flanges.

When little regard was paid to the cost of the procedure natural difficulties arising from the behaviour of the steel during solidification could be overcome, but, within a reasonable increase in cost, the occurrence of defects could only be obviated by modification in design. This raises the question of co-operation between designer and founder; because slight modifications to the design make all the difference between success and failure. There are well-understood principles which govern these details, though they are not reducible to a simple form. They are rather deductions which are nearly always suggested and applied by the founder. Less obvious and more difficult to arrange are those modifications of design which would result in cheaper pattern-making, less intricate, and therefore less expensive, moulding, and a decreased risk of failure to secure a regular production of sound castings.

Direct contact between the founder and the designer is not likely to lead to the greater simplification; according to the report, a third person of independent status is most likely to reconcile the essential demands of the one with the possible achievement of the other, and to modify the design in a manner which makes it both practicable and economical without impairing its utility. Some designs are put forward for castings which could not be made sound, and it is suggested that the next essential step in progress is in the design of castings.

The beneficial effect of the most striking advances in design may, however, be completely lost by inadequate safeguards in the way of the feeding and gating of castings enforced by an undue insistence on cheapness. If the very high standard demanded for highly-stressed castings is to be maintained it must be recognised that this standard is not easily attained, but that it involves a definite heavy outlay in special control of sands, make-up of moulds and cores, and in providing adequate feeding of the casting. It must also be admitted that the system of competitive tenders is apt to tempt steel founders to quote prices which may not fully allow for this heavy outlay, and then to avoid loss by undue economy in the provision of the safeguards mentioned.

When essential requirements under these three headings are recognised, the way is cleared for the more quantitative application of scientific principles to the manufacture of castings. This can only be made possible by a knowledge of the fundamental properties of the materials employed for both metal and mould. Though much remains to be done in the way of detailed investigation of the physical characteristics of these materials, important contributions to the knowledge of their properties are found in various publications, and a bibliography forms a useful part of the report.

A difficulty in the way of the rigid application of scientific principles in the steel castings industry is that every new design of casting is virtually a distinct and individual problem in itself, and therefore, even when the fullest physical data are available, an element of judgment will remain indispensable.

Personal.

Fry's Metal Foundries, Ltd., announce that on the formation of the new company, Fry's Diecastings, Ltd., Mr. A. O. Lord, who has represented them in the Birmingham and Midland District for some years past, has resigned. The duties of representative of the new company will be taken over by Mr. Arthur Street. Mr. Street is a native of Birmingham, son of Mr. Charles Street, of Moseley. He has had a very distinguished career at Birmingham University, has graduated in Metallurgy, took his M.Sc. and Ph.D. degrees. His thesis for the latter was on the researches on the copper-nickel alloys.

The degree of Dr. Ing. h.c. has been conferred on Mr. O. Waldrich of Siegen, by the Technical High School Fridericiana, in Karlsruhe, the oldest Technical High School in Germany, in recognition of his services in the construction and manufacture of heavy machine tools.

Forging and Rolling Temperatures of Steels—Part II.*

By J. H. G. Monypenny, F.Inst.P.

Continuing his discussion on the subject, in this article the author deals with the forging and rolling temperatures of alloy steels of various types.

IN applying to alloy steels the general principles on forging and rolling temperatures discussed in the first part of this article in regard to carbon steels, it will be convenient to consider first the ordinary alloy steels used so largely in aeronautical and automobile construction, and to a less extent in other branches of engineering. The bulk of these alloy steels may be divided roughly into three categories :—

(*a*) Those with a low carbon content, 0·1–0·15% or thereabouts, and intended mainly for case-hardened parts.

(*b*) Those containing somewhat more carbon, about 0·25–0·45%, and generally used in the hardened and tempered condition as high tensile steels ; and

(*c*) Those with a still higher carbon content, possibly up to 0·75% or so, and used for high-grade springs, forging machine dies, die blocks, high tensile tramway and railway tyres, and other similar purposes, where high tensile strength or resistance to wear is required.

From the point of view of hot-working characteristics, all these classes of alloy steels behave, broadly speaking, in a similar manner to carbon steels of the same carbon contents, though there are some differences. As a general rule, the addition of a small amount of alloy—up to 5 or 6% for example—tends to lower the melting point of the steel ; the safe maximum temperature of the alloy steel is likely therefore to be rather lower than that of unalloyed steel of the same carbon content. The difference, however, is not great, and for most of these steels containing up to about 0·5% carbon, a maximum temperature of 1,250° C. is suitable for primary hot-working operations—*i.e.*, those concerned with the production from ingots of blooms, billets, and slabs. For steels with higher carbon contents the temperature should be lowered in the manner previously indicated for carbon steels.

Similarly, for the production of the finished hot-worked article, the reheating temperature should be governed by the amount of work to be done, and should not in general exceed 1,150° C. As regards finishing temperatures, some structural differences between these steels and carbon steels may be noted. These alloy steels may contain up to 1½ or 2% chromium, either alone or together with small amounts of vanadium or molybdenum. Alternatively, nickel may be present in amounts up to 5 or 6%, and to these nickel steels may be added 1 or 2% chromium or molybdenum up to 0·5–1·0%. Another range of steels contains about 1½% manganese, either alone or in combination with small additions of molybdenum ; sometimes small quantities of nickel or chromium are also present. For very highly stressed parts, complex nickel-chromium-molybdenum or nickel-chromium-vanadium steels are frequently employed.

Considering these various combinations in some little detail, it may be noted that the addition of chromium to steel raises somewhat the temperatures at which A 3 and A 1 occur ; this would tend to raise to some extent the temperature, for any given carbon content, at which ferrite commenced to separate on cooling, but it is counteracted by two other characteristics of chromium steels—namely, the lower carbon content of their pearlite and their sluggishness in undergoing structural changes. Due to these opposing effects, alloy steels containing 1 or 1½% chromium (alone or with small amounts of molybdenum or vanadium) have structural changes on cooling at much the same temperatures as carbon steels of similar carbon contents.

Manganese and nickel, on the other hand, lower the temperatures at which these structural changes occur ; hence, in steels containing these metals, both the initial separation of ferrite and the transformation of austenite to pearlite take place at lower temperatures than in unalloyed steels of similar carbon content. In the case of a 3·0–3·5% nickel steel, for example, the difference may amount to about 100° C.

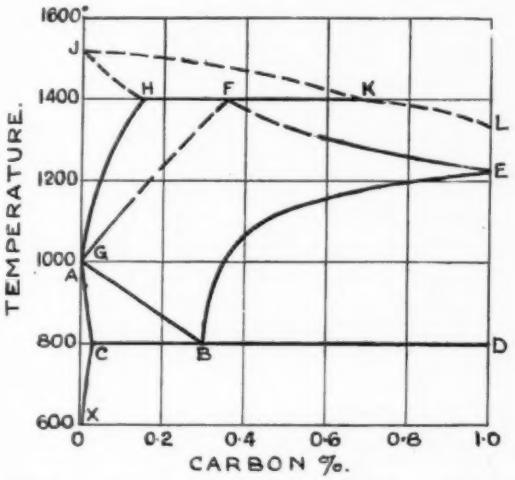


Fig. 6.—Section through the Fe-Cr-C ternary diagram at the 12% chromium plane.

The temperatures at which structural changes occur on cooling are still further depressed in the nickel-chromium steels of the air-hardening or semi-air-hardening types. These may remain completely austenitic until temperatures of 300–400° C. are reached.

The fact that these steels may thus remain entirely austenitic (and on that account are less likely to be produced in a "banded" form, due to hot working while possessing a duplex structure of austenite and ferrite) does not mean, however, that hot-working operations may be safely carried on to equally low temperatures. Most of these steels are distinctly stiffer at temperatures below about 700° C. than are the plain carbon steels, and hence may be deformed with less ease than the latter. The added stiffness may, in fact, be connected directly with the retardation, or absence, of structural changes because at any given temperature in the range in question, austenite is very probably distinctly stronger than ferrite, and possibly than pearlite also. It is not advisable, therefore, as a general rule, to continue working these alloy steels below about 700° C., and severe deformation should be avoided below 800°–850° C. in the harder varieties.

Two other points may be noticed. The scale formed on nickel-containing steels is much more adherent than that on carbon steels ; it is not so readily dislodged from the

* *Previous article published in March issue, 1933.*

steel during hot working, and may easily be forged or rolled into the steel. To minimise such troubles, care should be taken on heating nickel steels that they are not unduly scaled. The other point concerns the method of cooling those steels which are more or less air-hardening in character, after hot working is completed. On cooling from rolling or forging heats, such steels will harden to a greater or less extent, and, as a result, are likely to be in a state of internal stress when cold. The intensity of the stress will increase, other things being equal, with the rapidity and the unevenness of the cooling and, in unfavourable circumstances, may easily reach so high a value as to cause fracture. It is important, therefore, that forgings or rolled bars of air-hardening steels be cooled down as evenly and at as slow a rate as possible. These precautions should be noted particularly in connection with drop stampings, which are frequently of varying rather than of uniform cross-section. When air-cooled after stamping, the thinner parts cool rapidly, and may easily become rigid before the adjoining larger sections pass through the lowered Ar.1 change-point, with its inevitable expansion. The stresses thereby set up are quite likely to lead to the formation of cracks. For this reason, for example, particular attention should be paid to the "fash" on drop stampings of air-hardening steels; it is far safer to clip it off while the stamping is hot than to allow it to remain *in situ* when the stamping is thrown on the floor to cool.

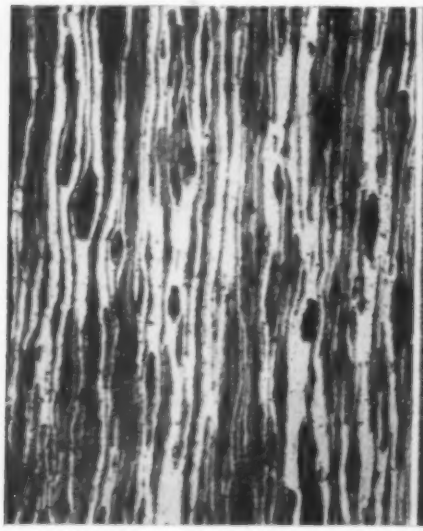


Fig. 7.—Banded structure of stainless iron plate, 15% chromium. × 60.

Fig. 8.—Decarburised skin of sample of 14% chromium iron after heating in a gas-fired muffle furnace at 1,150° C. for 20 mins. × 25.

In order to avoid undue wear on dies, high reheating temperatures are the rule rather than the exception, in the production of drop stampings. Even low carbon alloy steels will "burn," however, as many drop stampers have found to their cost in past years, and it is advisable to limit the reheating temperature, even for these, to 1,250° C., as was indicated earlier.

Tool steels containing small amounts—1 or 2%—of chromium or tungsten or both are dealt with in much the same way as ordinary tool steels of similar carbon content. For a given content of the latter, these alloy steels contain more free carbide, and are somewhat harder at forging temperatures than plain carbon tool steels. Overheating should be avoided, particularly with the chromium steels, which become coarse-grained almost as readily as carbon steels. On the other hand, working below 800°–850° C. should be done with care or cracks may result. Although not of the air-hardening type, these steels, especially those containing chromium, stiffen up distinctly on cooling from forging heats; it is advisable, therefore, to treat them carefully when cooling down after hot working, particularly large or irregularly sized pieces.

Proceeding to more highly alloyed steels, the family of stainless steels may be considered, and of these the 12–14% chromium type will have attention first, as their behaviour is the simplest. The usual temperature range recommended for hot working these steels is from 1,150° to 850° or 900° C., and, generally speaking, this should be adhered to. If a considerable amount of work is necessary at one heat, however, the initial temperature may be increased to 1,250° C. with safety. (Fig. 6 represents approximately a section through the ternary Fe–Cr–C diagram at the 12% chromium plane; melting commences at temperatures corresponding to curve J H F E.) Such a procedure is generally necessary, for example, when rolling billets into wire rod in order that the requisite reduction may be obtained before the rod has cooled to too low a temperature. No higher temperature, however, than is necessary should be used, on the score of surface conditions. High temperatures produce excessive scaling, and even if the scale be removed, the underlying surface is likely to be rough and pitted, undesirable conditions in a material which requires as one of its attributes perfection of surface.

At temperatures below 850°–900° C., these steels stiffen up very rapidly, particularly the higher carbon varieties used for cutlery and similar purposes. If attempts are made to deform them forcibly by heavy blows, when they have cooled below this range, they will be unduly stressed and may crack. More latitude is permissible with the lower carbon stainless irons, the rolling of which in bars of small section may often be continued down to 700°–800° C. without undue danger.

High chromium irons—*e.g.*, containing about 16–20% chromium,—and also the hardenable steels containing a like amount, and in addition about 2% nickel, are treated in much the same way. These irons, and also many of the hardenable steels of this type, do not become completely austenitic at any temperature; they always contain some free ferrite, and hence rolling and forging operations produce in them a more or less banded structure. Fig. 7, for example, represents the banded appearance found in the structure of a stainless iron (15% Cr) plate. Due also to this duplex structure, they are liable to tear when cut hot under hammer or press.

It should be noted also that these high chromium irons and steels are liable to have very sharply defined decarburised skins, which may possess a columnar structure very similar to that associated with hot cast ingots. The production of these skins is due to the action of chromium in lowering very markedly the temperature at which gamma iron changes to the delta form; see Fig. 6 and compare with Fig. 1 in the first part of this article. As a result, decarburisation may lead to the production at forging temperatures of a layer consisting entirely of delta iron containing in solid solution the carbon remaining unoxidised. As decarburisation proceeds to deeper levels, these previously formed grains of delta iron grow inwards in much the same way that solid grains of steel grow in columnar form during the freezing of hot-cast ingots. The minimum temperature required to produce such skins varies with chromium content, falling from 1,150°–1,200° C. at about 13% chromium, to 1,000°–1,050° C. at about 16%. As shown in Fig. 8, which represents the decarburised

band formed on a 14% chromium stainless iron after 20 mins. heating at 1,150° C., they have a very prominent structure, and may attain a considerable depth. Their production is to be avoided, as far as possible, in material which has subsequently to be cold worked in any way as their coarse, well-defined structure favours the formation of cracks.

With the exception of the lowest carbon varieties—*i.e.*, the stainless irons,—the stainless steels of these groups harden more or less intensely on air cooling from forging or rolling heats. Care should therefore be taken to cool them as evenly as possible in order to avoid the production of cracks. To this end, the forged or rolled articles may be cooled slowly in furnaces or in suitably designed pits lined with firebrick or other non-conducting material, or, alternatively, they may be charged back into a furnace at 650°–700° C., and held there until the austenite-pearlite change is complete, after which they may be air cooled with safety. The method is particularly suitable for small-sized articles of the 12–14% chromium steels in which the Ar. 1 change takes place with reasonable speed at the temperature stated; generally holding for an hour at this heat is ample. The method is not so suited, however, to the hardenable higher chromium steels containing 2% or so of nickel as the phase changes in these steels, taking place at much more sluggish rates, may require 24 hours or more for their completion. Slow, even cooling in some form of furnace or pit is preferable for these steels when there would otherwise be danger of cracks developing.

There is generally no need to cool the stainless irons slowly from forging or rolling heats, as they do not air harden to any great extent. In the case of the high chromium irons—*e.g.*, containing more than about 16%,—slow cooling is detrimental rather than otherwise, as it is liable to decrease their toughness below the rather low value which most of them possess under even the most favourable conditions.

Although the working of these hardenable stainless steels and irons, which have been heated to ordinary forging temperatures (1,000° to 1,250° C. or so) should not as a rule be continued below about 850° C., owing to danger of cracking, it is practicable to work small sections from an initial temperature of about 750° C.—*i.e.*, below the Ac. 1 point. When thus heated, they are ferritic, and they flow without undue danger of cracking, but require very heavy pressure, so that probably few mills or forging appliances are powerful enough to deal with bars finishing larger than about a square inch in section. The process is somewhat in the nature of cold-working in that the ferrite grains are distinctly elongated in the rolled bar and the tensile strength of the latter is raised by the process. In addition the rolled bars have high impact values. In order that the operation may be successful, the temperature must be carefully controlled; if too high a temperature is used the material may prove defective, probably owing to the greater hardness of the austenite which would be formed on passing through the Ac. 1 change, as compared with the ferrite of which the steels consist when not heated above the limit stated. For similar reasons, the process is more suited to the stainless irons than to the higher carbon steels. It should also be noted that for all such low-temperature forging or rolling processes, perfectly sound material is essential; for example, bars rolled in this way from billets prepared from piped or blown ingots are very liable to split longitudinally during the rolling operation.

The austenitic stainless steels of the 16–20% chromium, 8–12% nickel family are at least as hard at forging temperatures as the 12–14% chromium steels. They also may be forged or rolled between temperatures of 1,150° and 900° C. Below 900° C. they stiffen very markedly, and hot working at lower temperature than this should generally be avoided. In addition to being markedly harder, austenitic steels are also less ductile between 600° and 900° C., due to the separation of carbide which takes place as an intergranular network in these steels in this range of temperature. The loss of ductility is greater, the higher the carbon content.

Very similar considerations apply to the austenitic corrosion-resisting alloys of higher nickel content—*e.g.*, 20–40%,—which are used mainly for heat-resisting purposes, and also to the more complex alloys formed by adding other metals —silicon, molybdenum, copper, tungsten, titanium,—either to these higher nickel alloys or to those of the 18/8 or 16/10 types. Generally, these various alloys are more tender at forging heats than the simpler austenitic steels referred to in the last paragraph, and hence are more difficult to forge or roll. They are prone to cracking, and must be worked with great care, particularly in the early stages of dealing with the ingots. Generally speaking, 1,150°–900° C. is a suitable range of temperature for hot-working. Overheating must be avoided with the very high nickel alloys, as they "burn" at lower temperatures than those of lower nickel content. Many of these complex alloys, particularly those of the heat-resisting type, contain appreciable amounts of free carbide. In ingot form, this carbide often exists as a more or less continuous network round the grains of austenite, which form the bulk of the structure, in the manner indicated in Fig. 9. Occurring in this manner, the carbide is likely to cause the material to be tender in the initial stages of forging, as it provides a path along which fracture may easily travel. It is often advisable, when forging such an ingot, to heat it to 1,050° or 1,100° C., and give it, at first, a series of very light blows, after which it is again returned to the reheating furnace. This may be repeated, if necessary, a second time. This procedure effects a balling-up of the carbide network and also a recrystallisation of the columnar crystals of austenite which frequently characterise the ingot structure of these steels. With the breaking up of these structures the alloy becomes much less tender, and may be given increasingly heavier treatment at the hammer.

In all these austenitic alloys subsequent grain refinement by heat-treatment is not possible, of course, after hot-working. Heat-treatment is necessary to remove forging or rolling stresses and put the material in a satisfactorily soft condition, or to remove structural characteristics—

Fig. 9.—Carbide membranes in ingot of heat-resisting steel (0·4% carbon). ×50.

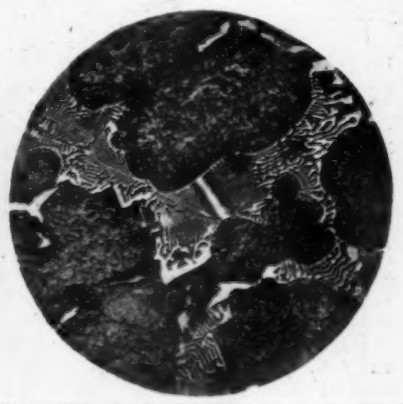


Fig. 10.—Eutectic in annealed ingot of high-speed steel. ×350.

e.g., free carbide,—which would have a detrimental effect on the corrosion resistance or other desirable property of the steel. As these heat-treatment operations do not refine the structure—often they tend to coarsen it—it is obvious that in cases where a fine-grained structure is desirable in the finished article, it must be obtained by careful control of the forging or rolling temperature, together with an avoidance of an unduly high softening temperature in any subsequent heat-treatment operation. Generally speaking, however, fine-grained structures are not so important, on the score of mechanical properties, in austenitic as in hardenable steels. The former do not generally lose their ductility even when they are quite coarsely grained.

The remarks regarding chromium-nickel steels containing large amounts of the latter metal apply also to the various iron-nickel alloys with 25% or more nickel, which are used for electrical and other purposes. These alloys generally forge either well or extremely badly, depending on structural characteristics produced during melting and casting. If their structural condition is favourable, they do not present any forging or rolling difficulties providing they are not burnt. If their structural conditions are unfavourable for hot-working, the only remedy as a rule is remelting.

Magnet steels may be grouped broadly into four categories :—

(*a*) The tungsten steels, containing about 6% of this metal and 0·7% or so of carbon, which have been a standard type of magnet steel for many years.

(*b*) Chromium steels, developed mainly for the purpose of replacing the relatively expensive metal tungsten with a cheaper alloy, and containing generally 2–5% chromium (though sometimes up to 6 or 7% is added), and 0·7–1·1% carbon.

(*c*) Cobalt-chromium steels whose composition is generally on the following lines : Not less than 1% carbon, 9–15% chromium, and up to 15 or 18% cobalt ; sometimes small amounts of tungsten, molybdenum, or vanadium are also present.

(*d*) The high cobalt steels—about 35%—whose magnetic properties were discovered by Prof. Honda and his colleagues ; these steels contain as a rule 0·4–0·8% carbon, and, in addition, chromium and tungsten may be added to the extent of 1–3% and 5–9% respectively.

As regards the first two groups, forging and rolling temperatures are broadly the same as for tool steels of similar carbon contents. For the tungsten steels, 800° C. is a suitable finishing temperature, the reheating temperature being adjusted to this end, but in no case exceeding about 1,150° C. The higher carbon chromium steels are more easily burnt, and in their case 1,100° C. should not be exceeded.

The cobalt-chromium steels should be treated in a similar manner to the 12–14% chromium stainless steels, except that stricter temperature control is necessary. Owing to their high carbon content, they are easily burnt, and for this reason should not generally be heated above, about 1,100° C. This figure may be raised to a maximum of 1,150° C., providing careful temperature control is exercised (partial melting taking place at rather over 1,200° C.), when a considerable amount of work is to be done, as, for example, in cogging operations. The steels are also harder at forging heats than those of the stainless variety, a feature which limits their hot working to temperatures above 900° C., in the case of small sections, and about 950° C. when larger sized pieces are being dealt with, as in preliminary forging operations.

The very high cobalt steels forge easily ; 1,100°–900° C. is a suitable range of temperature. It should be remembered that this material is brittle when cold ; ingots or bars should not be carelessly dropped or thrown about. Bending into required forms should be done hot, 800°–1,000° C. being a suitable temperature.

Magnet steels should never be annealed—*i.e.*, cooled slowly from temperatures above Ac. 1, in order to soften them ; such softening as is necessary for machining purposes should be done by tempering. The temperature will depend on the type of steel and may be about 700° C. for the tungsten steels, and rather higher—*e.g.*, 725° C. or so—for those containing cobalt or chromium. Annealing processes cause the separation of massive cementite, and, if this is formed, the magnetic properties of the finished magnet are inferior, even though the latter be hardened correctly subsequent to the annealing process. As fine structures are desirable on the score of magnetic properties, the steels should never be needlessly overheated. For example, when being reheated for bending or forging operations where little work has to be done on the steel, the bars or forgings should be heated rapidly to the required temperature (after suitable preheating to about 600° C. or so, should this be desirable to avoid any danger of cracking), and then bent or forged to shape without delay. It cannot be too strongly emphasised that the magnetic properties of a finished magnet are not solely a function of the composition of the steel and its final heat-treatment. They are influenced by all the reheatings the material receives between the ingot form and the finished product.

Manganese steel (12–14% manganese) is generally forged or rolled at temperatures between 1,050° or 1,100° C., and 850° C. Higher temperatures than those mentioned would lead to considerable danger of partial melting, though it is possible to use as high a reheating temperature as 1,150° C. —if the amount of work to be done at one heat renders it essential,—but very strict temperature control is necessary or the result will almost certainly be failure.

As there are at least half a dozen types of high-speed steel in general use, together with probably a number of others less widely manufactured, it may occasion some surprise that they are dealt with, in this article, more or less as one type of steel. It is worthy of note, however, that these various types of steel, although they may differ quite widely in composition—as is evident from the analyses quoted below, which typify one of the cheapest (A) and one of the most expensive (B) varieties of these steels,—yet they

	C %.	Cr %.	W %	V %	Mo %.	Co %.
"A"	0·6	3·5	13	—	—	—
"B"	0·75	4·5	20	1·2	1·0	10

present very similar characteristics. They are all essentially air-hardening steels, they all contain large amounts of free carbide—*i.e.*, they are all considerably hypereutectoid,—and (a detail of considerable importance from the point of view of forging and rolling operations) in the cast condition, a considerable proportion of this carbide exists as a eutectic which forms a more or less complete network round the grains of austenite, or the latter's decomposition products (see Fig. 10). Moreover, the crystals of austenite are arranged in columnar fashion from the ingot surface for part at least of the distance to the centre, and their boundaries are also the loci of much of the non-metallic impurities in the steel, as well as of the carbide eutectic. In ingot form, therefore, high-speed steels are likely to be extremely tender, and in the early stages of forging them this fact must govern the amount of work to be performed at each stage, otherwise an ingot, initially sound, is likely to break along its planes of weakness.

In passing, it may be noted that the presence of the abundance of eutectic in the cast form of high-speed steel is due to the fact that the maximum amount of carbon which can be dissolved by the austenite at any temperature short of melting is probably about 0·4%. During solidification, therefore, carbon in excess of this amount forms a eutectic of carbide and austenite. Incidentally, as the eutectic areas contain rather more than 50% carbide, a feature evident in Fig. 10, they are comparatively hard and brittle, even at forging heats.

Unless the ingot has been previously annealed, it must be heated very slowly and carefully until red hot, or cracks

(*Continued on page* 18.)

Strong Light Alloys of To-day

By Leslie Aitchison, D.Met., B.Sc., F.I.C.

During recent years considerable activity has been witnessed in the field of non-ferrous alloys based upon aluminium or magnesium. The author reviewed the situation in regard to these alloys in a paper recently presented before the Institution of Automobile Engineers, from the standpoint of a consideration of their ruling properties, and confined his attention particularly to those materials which are available and are employed in the wrought condition. The review is informative and comprehensive, and we are permitted to publish an abridgment in the following article.

THE developments in the wrought alloys have been much more numerous, and certainly more striking, than those connected with cast alloys, and it was considered desirable, in this instance, to neglect the latter type of alloy. For this reason attention was practically confined to those materials which are available and are employed in the wrought condition, comprising rolled metal, tubes, wires, forgings, drop-forgings, rolled or extruded bars and sections. Discussion of the alloys is based on four main considerations: medium-strength alloys; high-strength alloys; alloys strong at high temperatures; and corrosion-resisting alloys.

Before considering individual alloys and their properties, methods are discussed by which aluminium or magnesium may be strengthened. The first method is that of the simple application of cold work, which in general increases the strength, but impairs the ductility; and the second is that of heat-treatment, which usually involves the quenching of the alloy from an elevated temperature (below the solidus or lowest temperature in the freezing range), which quenching may or may not be followed by exposing the metal for long or short periods to the effect of some chosen temperature between that of the atmosphere and that from which the alloy was initially quenched.

The precise mechanism of all the constitutional changes that take place is not yet known at all exactly or completely, but it is generally agreed that the tempering operation involves a measure of breakdown of the solid solution that has been formed at high temperatures and preserved by quenching, causing the precipitation from the solid solution of some of the dissolved constituents, and most usually of the dissolved compounds. With certain aluminium alloys, this disintegration actually occurs at atmospheric temperatures, and then the operation is usually described as "age-hardening." With some other alloys, no disintegration takes place at room temperatures at all, but is brought about when the metal is heated to certain selected temperatures between 100° C. and 250° C., and in such a case the operation is usually described as "precipitation heat-treatment." By varying the composition of the alloy in the direction of altering the proportions of manganese, copper, iron, magnesium, and silicon, many interesting discoveries have been made, particularly in the direction of increased hardness or strength of the resultant alloy after precipitation heat-treatment. but all these elaborations are based upon the fundamental discoveries of Wilm upon age-hardening made about twenty-five years ago, which were as basic in the metallurgy of the aluminium alloys as was the accurate determination of the iron-carbon thermal equilibrium diagram in the metallurgy of steel.,

Medium-Strength Alloys.

Quite a number of elements can be added to aluminium in order to increase the maximum stress of the wrought metal to values between 12 and 17 tons per sq. in. Copper or zinc alone, or together, will go quite a long way in this direction, but the percentages of these elements which must be present is rather high, and the attainment of a really high strength involves a certain amount of cold work. As a result, the alloys produced are somewhat heavy. The most useful alloys in the medium-strength category are those which contain magnesium. These alloys, with or without a certain percentage of manganese, are relatively strong, and, in addition, they possess a fairly considerable resistance to corrosion, a resistance which is certainly very much higher than that offered by either the copper alloys or those containing zinc. Amongst these alloys are those known in the industry as D 2, 4 S, and Birmabright, the last-mentioned containing rather more magnesium than either of the other two, and consequently being a little stronger. The effect of the addition of magnesium to aluminium upon its mechanical properties can be seen from the figures given in Tables I. and II., the former table giving the results of tests taken upon the alloys in the sheet condition, and the latter the values obtained from them as extruded.

TABLE I.

Alloy, Sheet.		Maximum Stress, Tons per Sq. In.	Elongation, %
4 S	Soft	11·60	20·0
	Hard	18·70	3·0
D 2	Soft	12·50	24·0
	Hard	19·50	5·0
Birmabright	Soft	16·0	22·0
	Hard	22·5	6·0

TABLE II.

Alloy, Extruded.	Maximum Stress, Tons per Sq. In.	Elongation, %
4 S	12·5	20·0
D 2	13·5	20·0
Birmabright	17·5	18·0

The weeding-out process which follows from the industrial application of different materials has resulted in the elimination of almost all the other straight and non-heat-treatable alloys of aluminium, excepting those containing silicon. An alloy of aluminium containing from 8 to 12% of silicon possesses certain mechanical properties which just about bring it within the field under consideration.

Although the proportion of added element is high, the specific gravity of silicon itself is so low as to affect the density of the resulting alloy in a beneficial way, rather than the reverse. Variations in the silicon content of the alloys within the range indicated are not of great importance as regards the resulting mechanical properties.

The most interesting and useful "heat-treatable" alloy which comes into the class under consideration is undoubtedly that based upon a high percentage of aluminium, with the addition of approximately 0·6% of magnesium and 1·0% of silicon. An alloy of this composition is not extremely different in its properties from plain aluminium when simply extruded or rolled or annealed. If, however, it is heated to a temperature of 525° C. and quenched, it is rather definitely stronger than aluminium, and its properties in this condition can be seen from the test figures given in Table III. It is possible to alter the mechanical properties

of this alloy quite a good deal by subjecting it to precipitation heat-treatment, as shown in Table IV.

In this group may be included most of the wrought alloys of magnesium—*i.e.*, those containing more than 80% of this metal. But despite careful investigation, no alloy based upon magnesium has been developed which responds favourably to those heat-treatment processes that can be applied so successfully to the alloys of aluminium. The strengthening of magnesium, therefore, has to be brought about primarily by the introduction of suitable alloying elements into solid solution, and beyond that any additional strength must be achieved by means of cold work.

TABLE III.

Condition.	Yield-point, Tons per Sq. In.	Maximum Stress, Tons per Sq. In.	Elongation, %.
As rolled	8·00	12·50	10·0
As extruded	4·50	9·00	28·0
Solution heat-treated at 520° C. and aged at atmospheric temperatures	10·00	17·50	24·0

TABLE IV.

EFFECT OF PRECIPITATION HEAT-TREATMENT ON "H" METAL, SOLUTION HEAT-TREATED AT 520° C.

Temperature of Precipitation Heat-treatment, °C., 12 Hours.	Yield-point, Tons per Sq. In.	Maximum Stress, Tons per Sq. In.	Elongation, %.
100	12·80	19·50	20·0
120	13·70	21·00	18·0
155	15·50	22·50	15·0
175	21·00	25·50	11·5
200	19·00	23·50	9·0

The amount of cold work that can be applied successfully to the magnesium alloys is not very great, as the plastic distortion of these alloys in the cold state is a matter of considerable delicacy. Roughly speaking, therefore, the application of cold work to the alloys of magnesium really means the application of warm work, and even this in strictly limited amounts.

TABLE V.

ELEKTRON ALLOYS.

Alloy.	Manganese, %.	Zinc, %.	Aluminium, %.	Silicon, %.	Magnesium %.
A.M. 503	1·50	Nil	Nil	0·25	98·25
A Z M	0·30	1·00	6·30	0·20	92·20
VI.	0·30	0·30	10·00	0·20	89·20
C M Si	0·30	Nil	Nil	0·80	98·90

TABLE VI.

Alloy.	Proof Strength, Tons per Sq. In.	Maximum Strength, Tons per Sq. In.	Elongation, %.
A M 503 Sheet:			
Soft	7·5	13·0	11·0
Hard	8·5	15·5	5·0
A Z M Bar:			
Extruded	8·5	20·0	12·0
Forged	8·0	19·5	12·0
VI Bar:			
Extruded	16·0	22·5	8·0
C M Si	9·5	15·5	8·5

By suitably selecting the composition of the alloy, it is possible to obtain a material having a strength of 17 to 20 tons per sq. in., together with a reasonably high ductility, and since the specific gravity of such metals is only about 1·8 it is obvious that for certain constructional purposes, strong alloys of magnesium have certain definite uses.

The strength of magnesium is increased by alloying the metal with either aluminium by itself, or with aluminium plus additions of zinc and/or manganese. Table V. sets out the compositions of the most generally employed wrought alloys of magnesium—*i.e.*, the typical forms of electron,—whilst in Table VI. the mechanical properties of each of these alloys are given, both in the "normalised" condition, and also after the application of a certain amount of cold work.

High-Strength Alloys.

The decisive effect of magnesium upon the properties of aluminium, suggests that if still more magnesium were added to aluminium, a yet greater increase in the mechanical properties would be obtained. The alloy known as M G 7 can be included in this class. It will probably be helpful to set out here in greater detail the properties of this particular alloy after it has been submitted to varying degrees of cold work. The properties in question are given in TableVII., and these figures show that on the score of strength alone, M G 7 constitutes, for certain purposes, a very useful alloy; other properties possessed by this alloy, however, include resistance to corrosion.

TABLE VII.

EFFECT OF COLD WORK ON ANNEALED M G 7 SHEET.

Reduction in Thickness, %.	Yield-point, Tons per Sq. In.	Maximum Stress, Tons per Sq. In.	Elongation, %.
0	10·50	22·50	23·0
5·0	17·00	23·90	15·8
14·5	20·75	25·95	11·0
22·5	21·90	26·60	8·5
27·0	22·70	27·90	6·5
30·0	23·20	28·30	6·0
35·0	24·60	29·40	5·5
40·0	25·30	30·00	5·0

The rest of the alloys in this class are "heat-treatable," and of these, undoubtedly, the most widely known is duralumin, the chemical composition of which is approximately:—

	%
Copper	4
Manganese	0·5
Magnesium	0·5
Silicon	0·25–0·3

The standard heat-treatment given to this alloy consists in quenching it from a temperature of about 490° C. as rapidly as may be, followed by ageing at atmospheric temperatures. The changes in mechanical properties produced in duralumin by age-hardening at room temperatures are shown in Table VIII., and it is noteworthy that the rate

TABLE VIII.

Hours after Quenching.	Maximum Stress Tons per Sq. In.
0	16·5
1	16·8
2	17·5
5	18·5
10	21·5
15	23·5
20	24·5
25	25·0
30	25·5
35	26·0
72	26·5

at which the alloy hardens is not sufficiently great to render it impossible to carry out quite a considerable amount of mechanical work on the metal during the early period following quenching. If a pressing, a spinning, or other worked part is produced in duralumin during the first hour or so after it has been quenched, and the metal is then subsequently allowed to stand at room temperatures, it will, of course, eventually develop its full tensile strength of 25 to 26 tons per sq. in.

For duralumin of the normal type, precipitation heat-treatment is not of any practical value, and, in fact, if it is carried out at too high a temperature the operation may be severely detrimental. If, however, the chemical composition of the alloy is modified comparatively slightly, the response to precipitation heat-treatment is quite different, and it is this operation which has led to the development of alloys like M.T.E., super-duralumin, etc. When alloys of

the super duralumin type are subjected to a solution heat-treatment, the temperature which has to be employed is slightly higher than that used for duralumin, and the optimum figure is about 500° C. The alloys when quenched from this temperature and exposed to the ordinary atmospheric age-hardening operation undergo the changes corresponding to Table VIII. If, however, this alloy is then exposed to the effect of temperatures between 100° C. and 200° C. for a suitably prolonged period, "artificial ageing" is brought about by this heat-treatment, and the consequent changes in mechanical properties are clearly evident from the test figures given in Table IX.

TABLE IX.

EFFECT OF PRECIPITATION HEAT-TREATMENT ON SUPER-DURALUMIN, SOLUTION HEAT-TREATED AT 500° C.

Precipitation Heat-treated, 12 Hours at ° C.	Yield-point, Tons per Sq. In.	Maximum Stress, Tons per Sq. In.	Elongation, %.
100	20·20	27·5	15·0
120	21·50	28·7	12·0
140	23·00	29·5	11·0
155	24·60	30·35	10·0
165	23·30	28·75	9·0
175	23·00	28·0	8·0

A number of alloys have been produced by a greater or smaller modification of the duralumin composition, and generally call for the application of a precipitation heat-treatment, as distinct from plain age-hardening, in order to produce their maximum mechanical values. Probably the two best known of the alloys of this type are, firstly, "Y" alloy, and secondly, that group of materials usually known as the "R R" alloys. In all these materials, the composition of duralumin is modified by the addition of some other elements. Usually, also, the proportions of magnesium and silicon are changed, producing, in consequence, a very definite effect upon the instability of the solid solution obtained by solution heat-treatment.

"Y" alloy, which is the first departure from duralumin in point of time, has the following approximate chemical composition :—

	%
Copper	4·00
Nickel	2·00
Magnesium	1·50
Manganese	Nil
Silicon	0·30

The "R R" materials are very diverse in their composition, but it will, perhaps, not be wrong to take the following as indicating the range of elements present in the wrought materials :—

	%
Copper	1·5—3·00
Nickel	0·5—1·50
Iron	0·8—1·50
Magnesium	0·4—1·80
Silicon	0·4—1·25
Titanium	0·02—0·12

These alloys respond remarkably well, however, to the effect of precipitation heat-treatment, and the resulting properties of the alloys when subjected to this operation at different temperatures are set out in Table X.

High-Temperature Properties.

The subject of the strength of an alloy at high temperatures really needs to be regarded from two angles, the first being the actual mechanical properties possessed by the material in question at the temperature of test, and, secondly, the effect of prolonged exposures at high working temperatures upon the mechanical properties of the alloys after they have cooled down again to atmospheric temperatures.

Alloys which derive their strength from the application of cold work will obviously be permanently softened by a single exposure of adequate duration to a high temperature. Some others of the alloys, such as those which age-harden more or less completely at room temperatures, may be only slightly affected at all those temperatures below that at which annealing sets in, though exposure to temperatures superior to this will, of course, soften them. It is possible also that others of the alloys will become somewhat harder as a result of exposure to working temperatures (provided these are below the annealing temperature), and in becoming harder will also become more brittle. Such alloys might consequently be affected almost dangerously if used within certain temperature ranges.

Corrosion of Aluminium Alloys.

Numerous claims have been put forward from time to time regarding the relatively high resistance to corrosion of most of the alloys that are at present available in practice. It has been demonstrated, as a result of innumerable tests, that none of these alloys which are hardened by the presence of copper and of magnesium plus silicon and submitted to a hardening treatment, which involves the severe breakdown of the quenched solid solution, are highly resistant to corrosion. In the purely solution heat-treated condition, it is fairly evident from experimental data that such alloys may have a resistance to corrosion which is equal to, and may be, in fact, greater than, that of pure aluminium. Two such alloys may be referred to—one, the group of alloys containing duralumin "H," which, in the solution heat-treated condition, is highly resistant to corrosion ; and the other, which is not quite the same, is the alloy which is used as the outer sheathing on the plated metal known as "Duralplat." Both these alloys contain magnesium plus silicon, but the Duralplat skin also contains manganese. If, however, the alloy contains a solid solution which is unstable and liable to break down, the resistance to corrosion of the final product is decidedly lessened, and it is significant to note that the resistance to corrosion is much less in those alloys in which the solid solution is broken down by precipitation heat-treatment at temperatures over 125° C. than in those alloys in which the solid solution is unstable at room temperatures, and which age completely at that temperature.

TABLE X.

Precipitation Heat-treated, at ° C.	0·1% Proof Stress, Tons per Sq. In.	Maximum Stress, Tons per Sq. In.	Elongation, % on 2 in.
100	16·00	25·20	17·0
125	18·50	26·30	17·0
155	19·34	26·61	16·5
175	23·21	27·80	10·0
200	23·02	27·44	8·0

The presence of 2 to 3% of magnesium has a beneficial effect upon the corrosion-resistance of aluminium, and it has been suggested that the increase in strength of the aluminium alloy is roughly proportional to its magnesium content. When 3 to 5% of magnesium is present, the corrosion-resistance of the alloy becomes very considerable, and the addition of still more magnesium, up to approximately 7%, has a still greater effect ; at the same time, the mechanical properties of the material are good. It is apparently on the lines of developing alloys of this kind that the corrosion-resistance of aluminium is likely to be increased, and the alloys of this type are likely to find considerable favour with the automobile engineer.

Instruction in the Practical Control of Malaria.

Courses of instruction in the practical control of malaria, for the benefit of planters, engineers, and others in charge of labour forces in malarial districts have been held for a number of years at the Ross Institute, Putney Heath, S.W. 15. The course for the present year opens on June 19, and lasts until June 23. The course is free, and the Institute will welcome the attendance of any members of the Institution of Mining and Metallurgy who are interested in the subject.

Application for further information should be made to the Secretary of the Institute, Major H. Lockwood Stevens, at the above address.

Reviews of Current Literature.

Designing for Arc Welding.

ARC welding has made such remarkable strides during recent years that this book should invoke considerable interest. It is concerned primarily with the economic advantages of redesigning work to take full advantage of modern arc-welding methods. The facilities now available for the effective use of welding are applicable to all types of industry, and the results so far achieved open up a tremendous future for this form of assembling. The book contains the prize-winning papers submitted in the second "Lincoln" prize competition. These were judged to be the best from some 400 papers submitted, and include the work of foremost engineers in regard to the subject.

Divided into five sections, the text deals with machinery, shipbuilding, buildings, and bridges, large containers, piping, and fittings. In each case the fundamentals of design are so explained as to make them applicable to other industries. In designing machinery for welding, the principles involved are divided into two classes: one in which castings are displaced, and the other in which welding is substituted for riveting. Most of the principles given are concerned with the design and construction of various types of machinery. The use of welding in many phases of shipbuilding has increased rapidly during recent years, and specific examples of the application of fundamental principles are of special value to those engaged in this industry. Practically all branches of industry are concerned in this comprehensive work.

The use of arc-welded alloys to resist corrosion; the substitution of arc-welded steel for aluminium without weight increase; the welding of high tensile steels; structural design for the resistance of earthquake shocks—are a few of the interesting new developments which are discussed.

Every chapter of the book is written by an authority in that particular field. The total of these chapters represents the outstanding contributions of welding to industry during the past two years. The papers cover the subjects in great detail, and are illustrated with hundreds of drawings and photographs. The importance of saving in costs is emphasised.

Edited by A. F. DAVIS, who is an authority on arc-welding, the book contains about 450 pages, and is bound in cloth-covered boards. It is admirably prepared, and is published by the Lincoln Electric Co., Cleveland, Ohio, U.S.A. Price $2.50. Copies may also be obtained from Buck and Hickman, Ltd., 2, Whitechapel Road, London, E. 1.

Patents Explained.

THAT new inventions constitute stepping-stones in the progress of industry and manufacture should be obvious to all, and yet it is strange how often valuable inventions are given to the public without effort being made to secure the benefits of protection. The fact that this is so is due probably to a prevailing lack of knowledge of the patent system, and of the peculiar advantages it has to offer to all who evolve new and improved methods in manufacture.

The author of this book aims to correct this tendency by explaining in simple language the kinds of invention adapted for protection, the way in which a patent is obtained, and the effect of the patent when granted. The subject is outlined in a very comprehensive manner, and is bereft of those legal intricacies which can be relied upon to confuse and baffle the lay-reader.

Persons of a practical turn of mind would be well advised to keep this book handy for reference in readiness for the occasion when the subject of inventions or patents comes up for attention. It is also interesting to note that the book is quite up to date, and makes mention of the new provisions introduced by the Act of 1932.

Written and published by HERBERT J. W. WILDBORE, 101, Leadenhall Street, London, E.C. 3. Price, 5s. net; in pamphlet form, 8d. post free.

Forging and Rolling Temperatures of Steels

(*Continued from page* 14.)

are very likely to develop; its rate of heating may then be increased, but neither then, nor in the early stages if it has been previously annealed, should the heating be carried out in any way but slowly and evenly. High-speed steel has a lower thermal conductivity than ordinary steel, and even in the annealed condition is still comparatively tender; as a result, annealed ingots should not as a rule be charged cold into furnaces whose temperature exceeds about 600° or 700° C. It is also particularly desirable that the furnace atmosphere should be as reducing as possible; the use of a sharp oxidising flame is likely to lead to corner cracking during subsequent forging or rolling.

For the preliminary forging, 1,050°–1,100° C. is a suitable temperature, and when the ingot has been heated evenly to this degree, it should be given a series of light blows as it is moved slowly across the hammer faces. After this series of light blows, it should be returned to the furnace and brought up to about 1,100° C.; the forging may then be continued with still comparatively light blows, though heavier than at first, until its temperature has fallen to about 900° C. It is again charged into the furnace and brought up to a full forging temperature, 1,150°–1,200° C. The object of the alternate light forging and reheating is to break up the ingot structure to some extent and, when this has been done, the steel will stand much heavier blows of the hammer. The number of reheatings necessary to bring the ingot to a suitable bloom stage will depend on its size, the actual amount of reduction desired and the power of the hammer, but it is inadvisable to continue forging after the temperature has fallen to about 900° C. in the body of the bloom; the corners will then probably be between 700° and 800° C. Any further reheatings which may be necessary should be at a temperature of 1,150°–1,200° C. It should be noted that high-speed steels are much harder at forging heats than are ordinary carbon tool steels, and hence require reheating more often than the latter in order to effect a given reduction in section.

For the earlier stages of working high-speed steel ingots, forging is preferable to rolling. The preliminary light reductions which are desirable on account of the tenderness of the ingot structure are more easily arranged in forging. Once its ingot structure has been well broken up, however, high-speed steel can be rolled quite satisfactorily.

When rolling or forging billets or blooms to bars of the size required for tools or during any subsequent forging of these bars to produce some special shape, it is essential—if the best results are to be obtained—that the finishing temperature is such as will give a fine structure in the steel. If, owing to lack of proper control, the material, after forging or rolling is completed, possesses a coarse structure, the latter will persist to a greater or less extent through the subsequent annealing and hardening operations, and give rise to spangled fractures in the hardened tool. Owing to the hardness of high-speed steel at forging heats, there is a great temptation to reheat it to a full forging heat to facilitate working, even if only a small amount of forging is to be done. If a billet is to be rolled or forged to a bar of distinctly smaller size, a reheating temperature of 1,100° or 1,150° C. may be used, but only when the amount of reduction is such that work is continued down to a temperature of 850°–900° C. When only a small amount of shaping or forging is required, it is advisable to limit the reheating temperature to 975°–1,000° C., even if more than one heating is thereby made necessary.

Hot die steels, which may contain 9 or 10% tungsten, 3 or 4% chromium, and 0·3–0·4% carbon or thereabouts, and may therefore be regarded as mild varieties of high-speed steels, are treated in much the same way as their harder cousins. Due, however, to their lower carbon and alloy contents, they are less fragile and not so hard at forging heats as the high-speed steels, and may therefore be treated with more freedom than the latter. They should be worked, however, at similar temperatures.

The Iron and Steel Institute

Annual General Meeting

THE annual meeting of the Iron and Steel Institute, held at the Institution of Civil Engineers, in London, on May 4 and 5, proved to be as interesting and attractive to members of the Institute as many former annual meetings. Following the presentation of the annual report and financial statement for 1932, and the election of new members, the newly elected President, Mr. W. R. Lysaght, C.B.E., was inducted into the chair. His first duty as President was a pleasant one—viz., the presentation of the Bessemer Gold Medal to Dr. W. H. Hatfield, of Sheffield. In making the presentation, Mr. Lysaght said that by his scientific investigations Dr. Hatfield has opened up the way to new developments of great practical and industrial importance. He has succeeded in co-ordinating and developing co-operative research within the industry, and has promoted a general spirit of collaboration that is an important factor in industrial progress. In his scientific work he has always kept the practical end in view, and shown that when science is intelligently applied to industrial problems commercial success could be obtained. Dr. Hatfield played an important part in initiating and carrying through the researches which led to him being the first to demonstrate the qualities of certain austenitic chromium-nickel alloy steels. His work in connection with acid and heat-resisting steels was well known. In addition, he has rendered valuable service to the Institute.

Mr. Lysaght, in his presidential address, referred particularly to the sheet trade, an industry in which he has been engaged as a principal probably longer than any other living person. He reviewed some of his earlier experiences, and digressed somewhat to speak of chilled rolls, as a maker and user of which he was able to take an unbiassed view. Anybody who has had anything to do with a sheet mill is aware of the controversy that wages on the question of breakages. Periods occur when the calamities are few, and periods when they are alarmingly many. One roll will last 150 days, and another, cast out of the same ladle, with identical analysis and chill, one day. The increase from 18 in. to 34 in. in roll diameters during the last sixty years has not materially reduced the casualties, as the work required of the larger rolls is so much more strenuous than was formerly demanded. Thousands of experiments have been made, and every variety of pig iron tried, but no caster has yet made a roll that he is prepared to guarantee to last until it is worn out.

Referring to the future, Mr. Lysaght thought that when the world conditions returned to normal lost markets might be made up by a gradual increase of new uses for steel sheets at home, and by supplying overseas markets with qualities that they would probably not attempt to make for many years. He referred to the increasing application of sheet steel, and instanced motor-cars, furniture, electrical appliances, barrels, ceilings, concrete laths, etc., as examples of comparatively new sources of demand, while others were springing up constantly. Many technical papers on matters of particular interest to the iron and steel industry were presented at this meeting, only brief reference to which can be made here.

Coke Consumption in Blast-Furnace Practice.

The Effect of Removal of Breeze.

The presence of breeze in coke charged to a blast-furnace has several disadvantages, and blast-furnace operators generally agree that the use of hard cokes provide a means of lessening the amount of breeze, since they do not yield as much breeze as soft cokes in normal handling. With a view to obtaining quantitative data regarding the effect on coke consumption in the blast-furnace of removing breeze at different sizes of screen, all other conditions of working being maintained as constant as possible, tests have been carried out at a British blast-furnace plant. The trials were carried out for the Midland Coke Research Committee, and the results are given in a paper by D. F. Marshall, B.Sc., and Dr. R. V. Wheeler.

The removal of breeze at the furnace is one method of obviating the disadvantage of using a soft coke. It cannot be wholly effective, however, if, as is common, the coke after screening has to be dropped from a considerable height—6 ft. or more—before it reaches the stock level. The trials, therefore, should be regarded as preliminary to others in which harder cokes, which produce less breeze as the result of the same amount of handling, are to be used.

The authors show that the removal of a sufficient quantity of breeze, screened at 1¼ in. or 1½ in. from the coke, caused the particular blast-furnace studied to drive more easily. Incidentally, a by-product, coke-nuts, was obtained which commanded a ready sale. The records of coke consumption obtained from the observation of the furnace before, during, and after the trials, have been expressed on a basis of uniform slag production. These records suggest that no advantage is gained by screening out the coke breeze until between 6 and 9% has been removed.

From the estimates made as to the size of the coke at the stock level, coke of which as much as 95% passes through a 3-in. screen is quite satisfactory in a blast-furnace working under similar conditions to those of the trials. The results of the trials can therefore be taken as evidence confirmatory of the German and American experience that the most desirable coke for blast-furnace use should be, on arrival at the stock level, not greater in size than 3 in., and not less than 1¼ in. or 1 in., with the minimum amount of fine breeze.

The External Heat Loss of a Blast-Furnace.

In blast-furnace trials carried out by the Midland Coke Research Committee during a period of fifteen weeks, it was found that the average corrected "iron factor," calculated by the method devised by Evans and his collaborators,[1] was approximately 0·14 instead of the 0·5 or more to be expected from the average time of descent of the stock and the amount of burden. The most likely explanation of the abnormally low iron factor was that the external heat loss from the blast-furnace was lower than usual, and that the carbon burnt at the tuyères to meet radiation and external cooling losses was not represented by the actuarial average 500/D lb. per sq. ft. of hearth area per hour, where D is the diameter of the hearth in feet. A direct determination of the external heat losses was therefore attempted, the results of which are given in a paper by D. F. Marshall, B.Sc.

Comparison of Different Estimates of the External Heat Loss of a Blast-Furnace (B.th.u. per Pound of Iron).

	Bell.	Richards.	Johnson.	Clements.	Eichenberg and Oberhoffer.	Author.
Loss in cooling water	162	279	170	943	572	400
Loss by conduction to the ground ..	304	921	170	782		16
Loss by radiation and convection ..	324		440		592	64
Total	790	1,200	780	1,725	1,164	480

[1] *Journal I. & S. Inst.* 1928, No. 1, p. 53; 1931, No. 1, p. 95.

The values obtained and recorded are compared with estimates made by others, as in the accompanying table, the calculations being made on a common basis of B.th.u. per lb. of iron produced. In the present series of tests, the iron produced was approximately 10,000 lb. per hour.

The author discusses the results, and concludes that in the past the external heat loss of a blast-furnace may have been over-estimated, and that in a modern furnace with bosh sprays this loss of heat is mainly in the cooling water. If this conclusion is correct, it follows that other sources of heat consumption in a blast-furnace may explain the relatively large differences between the heat input and that accounted for in the thermal balances which have been constructed.

Recent Developments in American Blast-Furnace Design and Practice.

American policy of mass production was followed nowhere more religiously nor with better justification, during the period of steadily growing demand, than in the pig-iron industry. Changed conditions have, however, been a challenge to those in charge of this industry, and a test of their ability to reduce operating costs by means other than increasing production. Consequently, improvements for several years past have had for their chief purpose the conservation of labour and materials. In a paper on the subject by Wm. A. Haven, of Cleveland, U.S.A., the author summarises the means and methods that have been used to advance the art of blast-furnace operation and meet these changing conditions in America. No attempt has been made to infer comparisons between American and English or Continental designs or practices, the author appreciating that this could not be done fairly without mention of the circumstances that have dictated the nature and extent of developments in every case.

A comprehensive review of noteworthy accomplishments in this respect is concerned with practically all activities that are closely associated with the manufacture of pig iron, and the author divides the subject conveniently for the purpose of elaboration into stacks and auxiliaries; boilers, blowers, and electrical equipment; material handling; benefication of raw materials; reduction of metallic losses; reduction of thermal losses; utilisation of by-products; and operation and management.

Some of the most interesting developments in pig-iron manufacture during the last year are to be found in operating practices that were originally considered purely emergency measures, but that are now being hailed as permanent improvements. The most important of these has been "slow blowing." Recently, the pressure from the plant management has been to get as little tonnage as possible, while keeping the furnace in operation, not only for making the requisite amount of hot molten metal, but as a producer of gas for the manufacture of coke and coke-oven gas, the generation of power, and the heating of metallurgical furnaces.

This situation has resulted in "slow blowing," or blowing the furnace at a rate somewhere below the point of maximum production. Blast volumes were gradually reduced to keep pace with the operation of other departments. Many had anticipated serious operating difficulties from the building-up of the hearth, bosh, and stack, with resultant hanging and checking, but these were not encountered. On the other hand, surprisingly good results followed. Flue-dust losses were substantially reduced, the coke consumption was decreased, and the quality of the iron became more regular and better.

Structural Changes in Hypo-Eutectoid Steels on Heating.

This paper is the last of a series of three by Sir H. C. H. Carpenter, F.R.S., and Dr. J. M. Robertson, dealing with the structural aspects of the change from austenite to ferrite and pearlite on cooling and the reverse change on heating. The present paper is concerned with the structural changes above Ac_1, and with the effect of initial temperature on the structures obtained by cooling at different rates.

It is shown that during heating, ferrite is absorbed by the spread of austenite from the points originally occupied by pearlite. When heating is continuous, this results in the formation of a carbon gradient, which may affect the structures obtained on cooling from temperatures within the critical range. The experiments show, however, that this gradient has little effect on the structure obtained on cooling after 15 mins. at the initial temperature.

During moderately rapid heating the spread of austenite tends to some extent to follow the boundaries of the ferrite grains, and Whiteley[1] has shown that this tendency becomes more pronounced as the rate of heating is decreased.

For a given steel there are two fairly well defined grain sizes: (1) That formed when it is heated just above the critical range, and (2) that formed when it is heated to high temperatures. When the steel is in either of these conditions the grain-size does not appreciably increase with the time of heating. At intermediate temperatures it consists of a mixture of large and small grains, and the large grains continue to grow with time.

With a given rate of cooling, more ferrite is formed from small-grained than from large-grained austenite. The grain-size influences the amount of ferrite, because ferrite begins to form at the grain boundaries, whose number decreases as the grain-size increases.

The formation of the banded structure is affected by the initial temperature as well as by the rate of cooling. The higher the initial temperature and the longer the time of heating the more slowly must the steel be cooled in order to obtain bands. It is shown that repeated heating to a temperature just above the critical range does not produce a progressive decrease in grain size. Starting with large grains, one heating just above the critical range produces marked refinement, but repetition of this treatment produces only a very small change.

Formation of Columnar Crystals in Steel Sheets after Normalisation.

Large columnar crystals are often developed in normalised sheets after box annealing; the boundaries of these crystals are perpendicular to the surface of the sheet. In order to increase knowledge regarding their origin and growth, F. Kinsky, Met.Eng., has made experiments with 12- and 20-gauge sheets containing 0·085% carbon, 0·41% manganese, 0·018% phosphorus, and 0·014% sulphur.

Preliminary experiments (to examine the influence of the carbon content, rate of cooling, grain-size, distribution of ferrite and pearlite, heating medium, etc.) proved beyond doubt the relation existing between the grain growth and the rate of cooling after heating above A_3. Further experiments were designed to show whether the rate of cooling is the primary cause of this phenomenon, and what changes take place in normalised sheets cooled at different rates, in order to explain satisfactorily the various properties of box-annealed normalised sheets.

The author is of the opinion that the formation of large columnar crystals is due to small thermal intercrystalline strains set up by a rapid passage through the region of maximum segregation of α solid solution. The large, columnar crystals in normalised sheets appear after box-annealing in the A_1–A_3 range, when this is carried out in an oxidising medium. The prevention of the decarburisation of the sheets during box-annealing suppresses the immediate appearance of these columnar crystals, but the cause of their formation is not removed. These crystals appear after a fresh annealing in an oxidising medium.

[1] J. H. Whiteley, *Journal of Iron & Steel Institute*, 1932, No. 2, p. 289.

Some Comparative Corrosion-Fatigue Tests Employing Two Types of Stressing Action.

This paper, by Dr. H. J. Gough and D. G. Sopwith, B.Sc., describes some experiments designed to throw some light on the comparative influence of different stressing actions on the resistance of metals to corrosion-fatigue. Attention has been directed to the fatigue of a metal tested in air under reversed direct and reversed flexural stresses, and the general relation between the resistances under these conditions involves the important processes of stress redistribution and strain hysteresis, which possesses considerable theoretical interest. The present position regarding fatigue tests made in air is reviewed before describing tests in which an additional variable—a cooling environment of marked corrosivity—is introduced into the test conditions.

The corroding media employed was a fine (air-borne) spray of a 3% solution of common salt in distilled water. Six commercial materials were selected for tests; these included a cold-drawn 0·5% carbon steel, three non-corroding steels, duralumin, and a magnesium alloy containing 2·5% aluminium. The relative resistance of these materials to corrosion fatigue, under the test conditions employed, are summarised in the accompanying table, which indicates the approximate stress range required to produce fracture after endurances of 10, 20, 50, and, in some cases, 100 millions of cycles. The values of the fatigue resistances in air have also been inserted for reference purposes.

SUMMARY OF RESULTS OF FATIGUE TESTS IN SALT SPRAY.

Material.	Ultimate Tensile Strength Tons per Sq. In. T.	Endurance Limits. Tons per Sq. In. Reversed Bending Stresses.					Endurance Limits. Tons per Sq. In. Reversed Direct Stresses.			
		In Air. F_B.	In Salt Spray. fB.				In Air F_D.	In Salt Spray. fD.		
			10^7 Cycles.	$2 \cdot 10^7$ Cycles.	$5 \cdot 10^7$ Cycles.	10^8 Cycles.		10^7 Cycles.	$2 \cdot 10^7$ Cycles.	$5 \cdot 10^7$ Cycles.
0·5% C steel	63·2	± 24½–25¾	± 5·0	± 3·9	± 2·8	± 2·2	± 20¾–22¾	± 4·5	± 3·5	± 2·4
15% Cr steel	43·3	± 24¾	± 11·2	± 10·3	± 9·1	—	±21¾–22½	± 12·3	± 11·7	± 11·0
18/8 Cr–Ni steel	66·3	± 23¾	± 17·5	± 16·7	± 15·8	—	± 24¼–25½	± 17·2	± 16·1	± 14·8
17/1 Cr–Ni steel	54·5	± 32¾	± 15·0	± 13·8	(± 12·3) estimated	—	± 28¼–28½	± 17·2	± 16·4	± 15·5
Duralumin	28·2	± 9¼	± 4·5	± 4·0	± 3·4	± 3·0	± 6¾–9	± 3·4	± 3·0	± 2·6
Magnesium alloy (2·5% Al)	16·4	± 6¾	± 1·7	(± 1·0) estimated	—	—	± 5¼–6	± 1·0	—	—

Contribution to the Study of Inclusions in Steel.

In this paper Professor A. M. Portevin and R. Perrin, of Paris, state that the principal cause of the difference in the "qualities" of steels must be sought by the study of the inclusions contained in them; this has resulted in the accumulation of observations made over a number of years. The methods of investigating the characteristics of inclusions are reviewed, and the authors show that it is impossible at the present moment to determine the characteristics and define a steel, accurately and completely, on the basis of the inclusions which it contains.

The authors conclude that by the study of slags in equilibrium—obtained by microscopical methods indicated in this paper—knowledge can be obtained regarding the nature, properties, and individual structures of the inclusions formed under given conditions. This method of study, together with direct microscopic examination, carried out by means now available, and combined with improvements in the methods of analysing residues that are to be hoped for, will assure the progress of knowledge concerning this important problem in siderurgy. Thus, briefly, inclusions should be considered as an elementary slag in space and in time; in space because their very small dimensions permit of their assimilation to an element of volume, and in time because they develop in conjunction with the metal containing them or which gives rise to them.

The Influence of Phosphorus on the Properties of Hardened and Tempered Cast Iron.

Hardened and tempered cast irons are being used extensively in many applications in general engineering, and their properties should be more fully understood. The investigation contained in this paper by J. E. Hurst has been devoted to a study of the influence of phosphorus on the properties of an oil-hardened and tempered chromium alloy cast iron. The cast iron contained varying amounts of phosphorus from 0·35% to 1·56%, and the series were investigated in the as-cast, stabilised, annealed, and hardened and tempered conditions.

In the as-cast condition, it is found in the specimens examined that with an increase in the phosphorus content the Brinell hardness and EN value (modulus of elasticity steadily increase, and the tensile strength, area of stress/deflection curves and permanent set value steadily decrease. All the as-cast specimens harden to a Brinell figure of 500 and over after quenching in oil from a temperature of 875° C. The maximum hardening effect is obtained in the highest-phosphorus specimens and the minimum in those with intermediate phosphorus contents. Tempering at increasing temperatures after hardening is accompanied by a steady reduction in the Brinell hardness. In all cases the high-phosphorus specimens retain the maximum hardness until, with a tempering temperature of 600° C., all specimens show a practically uniform hardness whatever the phosphorus content. Tempering is accompanied by an immediate recovery in the tensile strength, EN value, and permanent set value. Stabilising generally lowers the tensile strength, Brinell hardness, and EN value. Broadly, the magnitude of the reduction is greater in the low-phosphorus specimens. A substantial increment in the stress/deflection curve area in all specimens is obtained in the stabilised, hardened, and tempered condition.

Annealing at 900° C., under the conditions specified, has had the effect of reducing the Brinell hardness, the amount increasing with the phosphorus content, and increasing the tensile strength. The lowest-phosphorus specimen is an exception, and shows a slight reduction in the tensile strength.

The hardening effect in the specimens subjected to the prior annealing treatment is accompanied by irregular results in individual specimens. The degree of irregularity is greater in the specimens with over 1% of phosphorus, and becomes less in the lower-phosphorus specimens, in which the hardening effect is practically equal to that for the as-cast condition. Above 1% of phosphorus the hardening effect in the hardened and tempered specimens is irregular, and in most cases is of a very small order.

The Effect of Sulphur and Phosphorus on the Corrosion of Iron.

It is found that localised corrosion of metals is connected with discontinuities, which constitute weak places of the natural oxide film. To avoid this dangerous type of attack, knowledge is necessary regarding those inclusions

at which localised attack is most liable to commence. The aim of the investigation, the results of which are given in a paper by Messrs. L. Tronstad and J. Sejersted, was to examine the effects of sulphur and phosphorus contents on the corrosion of iron. The programme included determinations of weight loss and oxygen absorption as measured by the reduction of a chromate solution. As a result of their investigation the authors conclude that, in ordinary iron and steel, phosphorus produces no appreciable effect, since it is present mainly in solid solution. A certain number of sulphide inclusions, however, initiate the anodic attack of the metal immediately around them, and thus stimulate localised corrosion. It is pointed out that a large proportion of the sulphide particles are nearly or completely inactive; the active character of the others may be due to the presence of crevices. The active sulphide inclusions seem to act as cathodes for corrosion of the hydrogen-evolution type, whereas in corrosion of the oxygen-absorption type, which is of greater importance, the cathodic process occurs at the main (uncorroded) area.

Internal Combustion Engine Exhaust Valve Failures.

More progress has been made in improved types of steel for exhaust valves than among any other steels used for automobile construction, but the requirements of such steels form a formidable array which no existing steel will fulfil. The two outstanding groups of these steels now used for high-duty exhaust valves are the silicon-chromium and austenitic steels. Little change has been effected in the former during the last ten years or so, but great strides have been made in the latter. Previous work on the subject provides results of experiments on the mechanical and heat-resisting properties of valve steels determined in the laboratory. In the present paper, by C. C. Hodgson, attention is confined to actual valves which have been used under service conditions, on bench tests or on the road, and to observations and deductions made thereon. The results cover many types of internal combustion engine valves, from those for light cars to those for heavy commercial vehicles of various makes.

Breakages are considered to be the result of corrosion-fatigue. Burning and cracking of the valves at their edges appear to be caused initially by small leakages of hot gases. These broad statements are believed to apply to all types of steels used for exhaust valves. In connection with burning, it would appear that trouble for which the steel has often been held responsible is mainly due to other causes. These factors are difficult of solution, and probably will never be entirely removed. The best steels so far developed are incapable of meeting these severe demands. To meet the requirements of an ideal valve, combining resistance of the seat to burning, high strength, and scale resistance in the neck, and the best wearing conditions for the stem and tip, would require a three-piece construction, or two-piece construction and selective surface hardening. Assuming that the obvious manufacturing difficulties were overcome, these methods would considerably increase the cost of a part already high-priced.

A Contribution to the Study of the Properties of Austenitic Steels.

Much experimental work has been done in connection with nickel-chromium steels in the Research and Development Department of the Mond Nickel Co., Ltd., and the research discussed in the paper by L. B. Pfeil, D.Sc., and D. G. Jones, M.Sc., was undertaken in order to throw further light on the relationship between the composition, rate of work-hardening, annealing temperature, and susceptibility to intercrystalline corrosion with special reference to the rôle of nickel. The results reported were obtained on 18-lb. heats of laboratory manufacture, but many of the conclusions drawn have been checked by studies of alloys of commercial manufacture. Steels containing 18% chromium were mainly used, a few being included with high chromium contents. Nickel contents varied from 8 to 29% and the carbon contents from 0·03 to 0·20%. Most of the steels, however, contained a carbon content near 0·10%. Experiments were also carried out on steels containing additional elements, and results are included for steels containing titanium and silicon, and also of a number containing molybdenum. Results indicate the probability that in all austenitic steels the rate of work-hardening is substantially unaffected by the temperature employed for softening. Work-hardening rate is decreased with an increase in the nickel content from 8 to 29%, the greater proportional decrease being made from 8 to 15%. An increase in carbon content from 0·04 to 0·1 increased the work-hardening rate, whilst a further increase to 0·2% resulted in a slight decrease in the work-hardening rate. Molybdenum tends to increase the hardness of the annealed material, but decreases the rate of work hardening.

Generally, softening occurs gradually with increasing annealing temperature. 18/15 steels were exceptions, which, with normal carbon, showed pronounced softening at 725° to 750° C. Carbon raises the softening temperature, while variations in nickel content also had a marked effect, reducing the softening temperature as the nickel was raised. Additions of molybdenum and titanium raised the softening temperature and increased the hardness in the fully softened condition. Increased annealing temperature renders the steel more susceptible to intercrystalline corrosion; the maximum temperature without this being developed varies with the composition. Titanium, silicon, or molybdenum additions are effective in raising the permissible annealing temperature. Increased resistance to intercrystalline corrosion results from the introduction of molybdenum or titanium into high-nickel steels.

Intergranular Corrosion of 18/8 Austenitic Stainless Steels.

The effect of short-time heating on the properties of the 18/8 stainless steels has been studied, and the results of the investigation are presented in a paper by E. C. Rollason M.Sc. The alloys examined comprised to straight, chromium-nickel steels with different carbon contents, and five modifications of these containing tungsten, copper, molybdenum, silicon, and tungsten plus titanium. The results show that the minimum time of heating necessary to cause "decay" is required at 750° to 650° C.; the actual temperature seems to be a function of the carbon content. Above and below this temperature the time of heating increases, giving rise to two curves suggestive of asymptotic values. The slope of the lower curve can be expressed as:

$$\theta = KT^{-0\cdot065}$$

where θ = temperature, ° C.,
T = time of heating,
and K = constant,

with a definite asymptotic value below 450° C.

In steels containing similar amounts of chromium and nickel the susceptibility to disintegration is increased by an increase in the carbon content. The addition of 0·59% of tungsten with 0·15% of carbon displaces the curve to the right, but the increased resistance is not so great as that obtained by reducing the carbon to 0·11% in a similar straight 18/8 alloy. Although 2·02% of copper increases the general resistance to dilute hydrochloric and sulphuric acids and ammonium chloride, the resistance to intergranular attack after reheating in the range 500° to 750° C. is reduced.

The pretreatment of the alloys materially influences the resistance to intergranular corrosion. Temperatures above 1,100° C. are conducive to a greater concentration of carbon in supersaturated solution and to a large grain-size, with a consequently smaller "boundary area" in which to precipitate the carbides. Small grain-size can be obtained by

(*Continued on page* 28.)

The Phenomena of Quenching and Tempering in Alloys

Two principal means of improving the properties of metals and alloys are available to the metallurgists: the preparation of alloys and making use of heat-treatments. In the May Lecture, delivered to the Institute of Metals on May 10, Professor Albert Portevin discussed the latter means, abstracts of which are given in this article.

THE study of thermal treatment is often of even more practical inportance than the search for new alloys; besides, the useful effect of the addition of new elements to a metal is generally entirely dependent on a thermal treatment, without which the result would be of little interest. For a long time steel was the only metallurgical product to which quenching and tempering were industrially applied; later, other alloys, such as "aluminium bronze," appeared to present analogous phenomena which were susceptible of practical use, and quite naturally one sought to connect their mechanism and the laws with those of steel.

For some time these few examples remained isolated facts, and the application of thermal treatment was exceptional and was limited almost exclusively to steels and bronzes. Towards 1911 Wilm discovered, in alloys formed by the addition of magnesium to commercial aluminium, the phenomena of spontaneous hardening after quenching. This appeared astonishing, and its mechanism was discovered only several years later, as a result of remarkable researches, in particular those of the English school represented by Rosenhain and his collaborators. These light alloys containing magnesium were at first regarded as an exception; later on, similar results were obtained simultaneously by Zay Jeffries in America, and by the author in France, with other light alloys containing copper and without magnesium. These phenomena, which differ from those of quenched steel, were extended to many other alloys, and further examples are continually being brought to light.

The study of quenching and tempering phenomena has for its objective to find, to put forward, to define, and to measure all the modifications accompanying these thermal treatments, certain inner modifications appearing as the cause, the origin, or the explanation of other modifications which are more visible, more utilisable, and which will be considered as effects and consequences of these phenomena. One can say, in short, that there has been an effect caused by thermal treatment if the thermal cycle leads to any modification of one of the properties or one of the characteristics considered. But it is important to distinguish carefully between two large classes of modifications:—

1. Specific or local modification affecting the constitution, the structure, and the properties of the part of the metallic mass under consideration as a function of the thermal cycle described by this part independently of the rest of the piece.

2. General modifications which affect the properties or the characteristics of the whole piece, such as its shape, its dimensions, its internal stresses, and, consequently, its general mechanical properties, and which are functions of the divergencies existing between the thermal cycles undergone by different parts in the piece. In other words, if θ is the temperature, t the time, and x, y, z are co-ordinates of a point in the interior of the piece, the result of these general modifications will be a function of x, y, z, θ, and t right through the piece; whilst the modifications of the first division, specific or local modifications, will be functions of θ and t, functions related to the position x, y, z of the point in the interior of the piece.

Up to the present the hypotheses and theories of quenching, no matter how ingenious and attractive they may be, have not brought about any revolution, and have not led metallurgists to discover any new fact or to foresee any phenomenon, and their practical importance has been nil. One must not, however, lose hope, and the future will doubtless show their utility—perhaps they have simply been premature, and conceptions more directly related with established laws will show themselves more fertile.

Experimental Methods.

Considerable progress has been effected in the last 20 years in experimental technique and in the apparatus used, so that the methods of thermal analysis have been greatly improved, and other methods have been introduced or have been standardised, such, for example, as dilatometric analysis and thermo-magnetic analysis. Finally, the study of crystalline structure has benefited by a superb method of investigation—X-ray spectroscopy. In spite of that, the study of the quenched states—*i.e.*, of non-equilibrium conditions—remains incomparably more complex than that of equilibrium conditions, for the modifications that they undergo or that bring them into existence are transitory and often rapid, being irreversible and unstable. One must observe the transformation at the actual moment when it is taking place, and a very small variation in the thermal cycle, or in the initial state, or even in the period at which one makes the observation, may introduce profound modifications into the mechanism of the reaction and into the state of the metal at the moment of observation. It may easily be true that determinations carried out on the same sample under non-identical experimental conditions, or on different samples, or by different experimenters will not be rigorously comparable. Finally, the modifications are complex, and a single method of research is in general insufficient to clarify the phenomena.

In our opinion it follows from this that the experimental method used must necessarily satisfy the following conditions: Multiplication of methods of study, and carrying out of the determination at the same time on the same sample after the same treatment; and use of "dynamic" methods of study, observing the phenomena while they are taking place—*i.e.*, during thermal treatment, and, if possible, recording the results of this evolution, preferably to static procedures which examine the metal only at the end of the treatment.

The two methods of study must be used conjointly, as Osmond first showed when he established the fundamental relationship between the procedure of the observed transformation during cooling and the results obtained by micrographic study after this cooling.

Conditions, Possibilities, and Circumstances of Quenching of Alloys.

In order to obtain quenching effects on cooling a material which has been heated to a temperature θ, it is obviously necessary that the chemical equilibrium constitution which exists at θ must be different from the chemical constitution at ordinary temperatures; for, were they identical, no modification would take place during cooling, however rapid it were.

Restricting ourselves, for the sake of simplicity, to binary alloys, one can say that almost all cases of quenching may be connected with the two following:—

(A) The increase on rise of temperature of the concentration of a phase α in a mixture $\alpha + \beta$; in other words, increase of solubility in the solid solution α of a phase β which is frequently a chemical compound (or intermediate phase of the diagram).

(B) The transition on heating of a mixture of two phases $\alpha + \beta$ into a single phase γ.

These two cases (A) and (B) each represent, from a practical point of view, examples of the oldest and the most important thermal treatments : (*a*) that of light alloys of aluminium, and (*b*) that of steels.

After discussing these phenomena and their laws in these two great typical cases (A) and (B), the author generalised on the observed facts, dealing with the conditions of quenching and laws of quenching and the laws of tempering.

Commonness of the Phenomena.

These phenomena of quenching with structural hardening or precipitation hardening, starting from a supersaturated solid solution, are extremely numerous ; one continually finds new examples, and, remembering what we have said about the mutual solubility of phases, one can deduce that this phenomenon, first considered as exceptional, is, on the contrary, most common in the case of quenching alloys.

It is of particular interest that the result depends on the difference between solid solubility at high and low temperatures, and not on the mean solubility. Further, the accelerating effect of deformation on precipitation explains the phenomena of mechanical and magnetic ageing of steels. It may be noted that the hardening element is very often a definite compound formed either by the addition of a new metal or element to the basis metal. Thus a whole series of alloys becomes available the study of which, already begun, opens a new field of research and of application.

A characteristic of these alloys is the zone of hardening temperature which stretches between the temperature θ of commencement of perceptible tempering to the temperature of commencement of coalescence—*i.e.*, that in which "ageing" takes place and which often coincides with the zone of tempering after working ; both these phenomena being connected with the mobility of the atoms. Two interesting cases were considered :—

1. Those in which this zone includes room temperatures. They are those ofrspontaneous hardening by tempering like Duralumin, which cannot be kept in the soft-quenched state except by keeping it at a low temperature (for example, the use of carbon dioxide snow for Duralumin rivets).

2. Those, on the other hand, where this zone is at an elevated temperature, in which case we can obtain alloys retaining their hardness while hot, or even hardening while hot.

Relation Between Phenomena and the Problem of Quenching.

In order to complete the exposition the author found it necessary to consider in its totality the practical problem of quenching, and, after having analysed all the phenomena and discovered the laws, to make a synthesis of it considering the operation in all its complexities under all its appearances, and all its manifestations, taking note of all the practical applications thereof. Further, it would be necessary to consider :—

1. The structural modifications accompanying heating, especially the coarsening of the crystal grains, as well as the influence of the initial state.

2. General modifications which accompany all cooling, geometric modifications or deformations, modifications of internal mechanical equilibrium (stresses and cracks), phenomena which are complicated by the effect of the shape and the dimensions of the pieces and concerning which we have endeavoured to obtain some general laws.

3. The final mechanical properties which are required, in particular, strength or hardness, and shock strength.

4. The uniformity attained—*i.e.*, penetration of the quench.

5. The conditions which can be obtained in practice—*i.e.*, the cooling media which one can use (in general, water, oil, molten metals, air).

A New Lead Alloy.

Cheaper and Better Water-Pipes.

IN view of the very extensive programmes for building, it is gratifying to learn from a report just issued by the Department of Scientific and Industrial Research the welcome news that scientific research has produced an alloy which has resulted in the saving of 20 to 30% in the cost of raw material used extensively for water-pipes, roofing-sheet, guttering, and other applications in every class of building.

This scientific achievement is the result of extensive metallurgical investigation conducted by the British Non-Ferrous Metals Research Association and at the Research Department at Woolwich. The practical testing of this new discovery, which is of far-reaching importance, has been carried out by the British Water Works Association, who, in an official circular, make definite recommendations for its adoption. Licences for its manufacture have been granted to the majority of the lead manufacturers in this country.

The great saving in cost is due to the fact that this alloy is 30% lighter for the same strength than ordinary lead, which not only results in the saving of as much as 30% in the metal costs, but also in a saving of freightage and handling charges, which, with such a heavy material as lead, is no small item. Apart from the saving in cost, this new alloy has other advantages. Not only has it a far greater resistance to fracture by vibration, which is an increasing trouble due to the enormous growth in heavy traffic, but also where lead suffers from corrosion through contact with such alkaline substances as lime and cement-mortar the new alloy is definitely more resistant to attack. It is surprising that these results are achieved by the addition of less than 2% of tin and cadmium to the lead.

The report* which has just been issued by the Building Research Board under the chairmanship of Sir George Humphreys, K.B.E., M.Inst.C.E., will undoubtedly prove of great value to all who are engaged in constructional work.

* Department of Scientific and Industrial Research : Building Research Report No. 19. H.M. Stationery Office. 9d.

Foundrymen's Conference at Cardiff.

THE Annual Conference of the Institute of British Foundrymen this year will be held at Cardiff, from June 20 to 23 inclusive. It is twenty-one years since the Conference was held at Cardiff, and since then the Wales, Monmouth, and West of England Branch of the Institute has come into existence, the members of which are responsible for the arrangements of this year's Conference. Cardiff is a very attractive city, and the programme arranged for members and their friends attending the Conference will enable visitors to obtain full benefit from their visit to South Wales.

Papers presented at the technical sessions held in conjunction with this meeting will include :—"Modernised Foundries," by F. J. Cook, M.I.Mech.E. ; "Routine Methods of Testing Green Sands," by the Sands Sub-Committee of the Technical Committee ; "Alloy Grey Irons," by Dr. Ing. C. W. Pfannenschmidt ; "Heat-resisting Cast Irons," by E. Morgan, M.Sc. ; "Alloy Cast Iron," by Frank Coyle ; "The Anodic Treatment and Dyeing of Aluminium Castings," by N. D. Pullen, A.I.C. ; "Coke Practice in the South Wales District," by W. R. D. Jones, D.Sc.

NITRICASTIRON: Cast Iron Suitable for Hardening by the Nitrogen Hardening Process

By J. E. Hurst.

In comparison with ordinary cast iron Nitricastiron shows a higher strength, a higher modulus of elasticity, a lower permanent set value and a greater intrinsic hardness, and, as its properties become more widely known, its uses will extend.

A GREAT deal of interest has been aroused by the development of cast iron suitable for hardening by heat-treatment. The most recent addition to cast iron within this category is Nitricastiron, an alloy cast iron suitable for casehardening by the nitrogen hardening process. This process in its application to steel is now familiar to most engineers under the name of the Nitrarding process, and the special alloy steels suitable for the process are known as Nitralloy steels. As in the case of the special steels, the essential alloy additions present in Nitricastiron and to which it owes its susceptibility to the nitrarding process, are aluminium and chromium. The chemical composition and properties of aluminium chromium cast iron within the range of commercial Nitricastiron have been described by the author in a paper before the May meeting of the Iron and Steel Institute last year. A typical chemical composition is as follows :—

	%
Total carbon	2·75
Silicon	2·75
Manganese	0·75
Phosphorus	0·10
Aluminium	1·75
Chromium	1·75

Nitricastiron, as compared with ordinary cast iron, in all cases shows a higher strength, a higher modulus of elasticity, a lower permanent set value, and a greater intrinsic hardness. Nitricastiron is susceptible to heat-treatment by hardening and tempering, and is also distinctly air-hardening. When exposed to the action of anhydrous ammonia gas at a temperature of 500° C., under the conditions of the commercial nitrogen hardening process, it is accompanied by surface hardening, and a diamond hardness value of 982 is attained. This value is much harder than glass and quartz, and somewhat less than that of a beryl. A depth of penetration of 0.018 in. on the centrifugally cast specimens was obtained with a 90-hour treatment under standard conditions.

The furnaces used are of the electrical resistance type, provided with automatic regulation features. The articles treated are placed loosely in a gas-tight box without any packing material. The box is provided with inlet and exit tubes for the passage of the gas. The illustration, Fig. 1, shows a box completed ready for inserting into the furnace. With the current of gas flowing at a pressure of about ½ in. to 1 in. water gauge, and maintained at a temperature of 510° C. the ammonia undergces dissociation, and some of the nitrcgen is absorbed by the articles, the exhaust gases passing frcm the box consisting of undissociated ammonia, hydrogen, and some nitrogen. Control of the process is exercised through the extent of this dissociation. This is pericdically checked throughout the process, and maintained by adjusting the flow of gas at a value of approximately 30% dissociation. If the dissociation value is too low the current of gas is retarded ; if too high the current of gas is increased. The temperature control is maintained by automatic regulation to within plus or minus 5° C.

Selective hardening can be effected by the use of tinning or the application of protective paint to the surfaces required to be maintained soft. Tinning is performed, utilising a good lead/tin solder applied to the surfaces after cleaning and treating with zinc chloride flux. Excess of tin coating is undesirable, and is removed by wiping the surfaces during the operation. Protective paints made up of powdered aluminium and sodium silicate or chromic oxide and sodium silicate are also effective. Such paints are generally applied with a brush, and the articles thus painted require to be thoroughly dry before submission to the nitrogen hardening treatment. These paints can be removed readily after the hardening treatment by the application of boiling water.

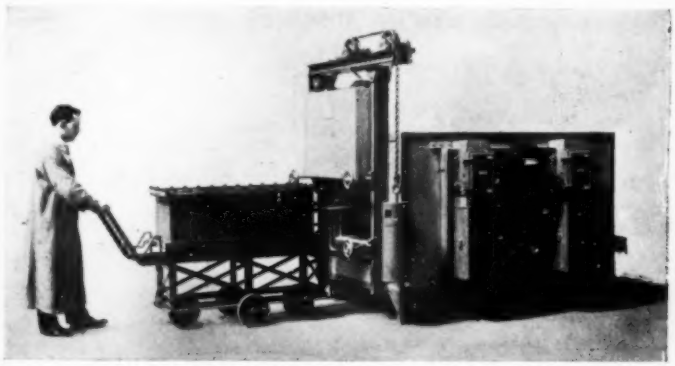


Fig. 1.—Nitriding furnace showing automatic regulation and box being charged.

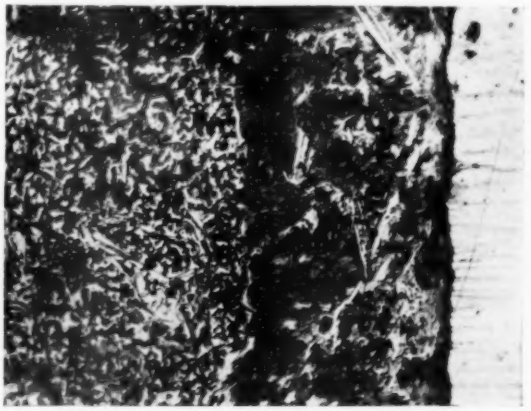


Fig. 2.—Extreme edge of nitrided cast iron × 200 diameters, etched picric acid.

The duration of the hardening treatment is about 80 hours, and with this a depth of penetration of over 0·015 in. is obtained. Where depth of penetration is unimportant a shorter period can be adopted, and treatments of 40 to 60 hours' duration are quite common. After this treatment the articles are allowed to cool, and no further treatment is necessary to render them hard. The extreme outer skin shows a matte grey colour, and for a depth of approximately 0·001 in. the surface is of a soft, friable nature, which can be removed readily by simple operations, such as polishing or grinding, when the surface of maximum hardness is revealed. A microphotograph of the extreme edge of nitrogen hardened cast iron is illustrated in Fig. 2, and shows the characteristic structure of the case as

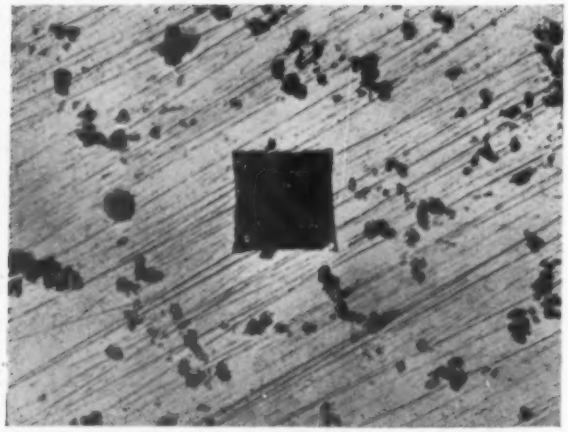


Fig. 3.—Diamond hardness impression on nitrogen hardened surface, showing absence of spalling, × 110 diameters.

outlined. Whilst the best results in so far as hardness and depth of penetration are obtained by hardening castings having their surfaces finely machined or ground, quite satisfactory results have been obtained in individual cases by hardening unmachined castings whose surfaces have been prepared by sand blasting. The results obtained under these conditions are somewhat inferior to those obtained with machined surfaces, but they have been found quite satisfactory for particular requirements.

The hard casehardened surface is perfectly coherent and free from liability to spalling and flaking. This is demonstrated by the absence of such spalling effects in the diamond hardness impressions made during the hardness determinations, and also the absence of such effects when testing hardened specimens in bending for the determination of the ultimate breaking strength. An illustration showing a typical diamond hardness impression is shown in Fig. 3. The absence of spalling will be noted. This illustration is of interest also in showing the presence of graphitic areas in the case-hardened surface, due to the presence of free graphite in the alloy. It is considered by many people that the presence of such graphitic areas is distinctly advantageous in surfaces called upon to withstand wearing action.

This stability of the casehardened surface is definitely superior on castings which have been hardened after subjection to a preliminary heat-treatment. Two heat-treatments are available; the simpler of the two consists of heating the castings to 900° C. and allowing to cool in still air. The second heat-treatment consists of oil-hardening and tempering, which is carried out by quenching the castings in oil from a temperature of 850° to 875° C. and tempering at a temperature of 600° to 650° C. The effect of this treatment is to convert the pearlite into the sorbitic or spheroidised condition. Incidentally, in this condition the structure of Nitricastiron is similar to the spheroidised cast irons, which have been referred to in recent descriptions of American practice relating to high-duty cast irons.

For the removal of internal stresses, the castings are stabilised by treating at a temperature of 600° to 650° C. for periods of from half to two hours. The tempering operation in the second heat-treatment above mentioned is equivalent to this stabilising treatment. The effect of this treatment is to remove internal stresses which would produce distortion in the subsequent hardening treatment. In the hardening treatment a slight change in dimensions is sustained by the castings. The magnitude of this can be judged from the fact that a 1-in. diameter round bar increases in diameter by 0·0015 in. after a 90-hours treatment.

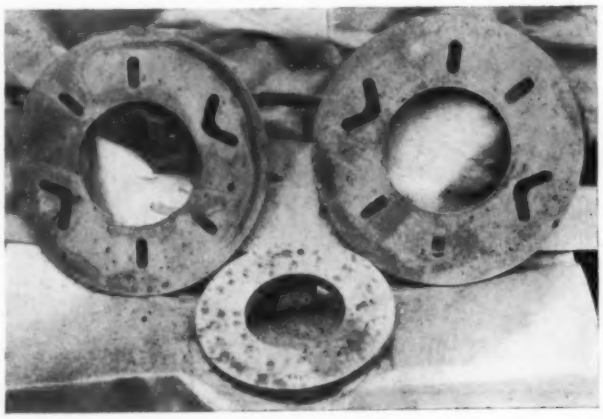
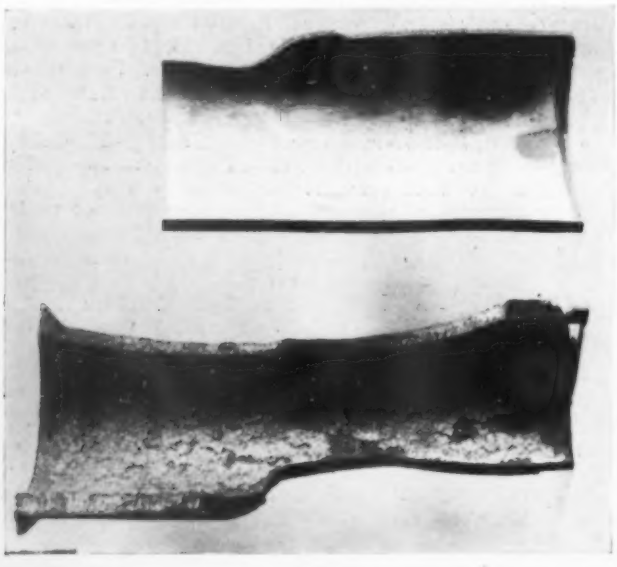


Fig. 5.—Wear plate castings in Nitricastiron.

Fig. 7.—Rotary valve castings in Nitricastiron.

Fig. 4.—Ordinary cast iron and Nitricastiron after exposure to atmospheric conditions for nine months.



In considering the general properties of Nitricastiron, the investigations already conducted have shown clearly that the strength properties in so far as ultimate breaking strength and freedom from brittleness are quite satisfactory. In fact, Nitricastiron is considerably superior in these respects to ordinary cast irons in view of its higher strength and greater freedom from brittleness. The higher modulus of elasticity is a property of very great importance in many applications, as it indicates a greater stiffness and a higher resistance to deformation under a given stress value. The very low permanent set values at all stresses clearly differentiate Nitricastiron from ordinary cast irons. This property, together with the high modulus of elasticity, is of importance in considerations of cylinder wear, where a good deal of the wear is brought about by deformation due to the stresses set up at the planes corresponding to the reversal in direction of the piston. The freedom from permanent set is also a consideration in those applications of cast iron where interference fits are required,

and the absence of permanent set ensures the prolonged maintenance of the fit.

The nitrogen-hardened surface is definitely of superior resistance to corrosion, and in all probability its properties in this direction are very similar to those of nitralloy steels. Hardened Nitricastiron has already been tested for resistance to atmospheric corrosion. The photograph, Fig. 4, shows samples of Nitricastiron and ordinary cast iron to Air Board Specification 4K6, after exposure to the works' atmosphere for nine months. The ordinary cast iron is badly corroded, whilst the surface of the Nitricastiron is practically unaffected. This property is of additional value in considerations of the use of Nitricastiron for cylinder liners, where the corrosion on the water-jacket side is in many cases undesirable. By nitrogen-hardening the external diameter of such liners, the corrosion in the water-jacket space can be minimised considerably. It is also anticipated for the same reasons that the nitrogen-hardened surfaces will minimise the risk of corrosion fatigue.

In addition to its applications for cylinder liners, Nitricastiron has already been applied to a variety of cast-iron valve parts, pump parts, and machine-tool parts. It has found applications in the various parts of textile machinery, and interesting applications arise in general engineering, tool-room, and millwright work for jig parts, gauges, pulleys, wearing collars, and bushes. The illustrations, Figs. 5, 6, and 7, illustrate various valve parts and castings used in the construction of coke-oven handling machinery, and are typical examples of the type of castings already produced. In handling machinery of all types there are numerous castings where the high strength and excellent wearing properties of this material should prove invaluable.

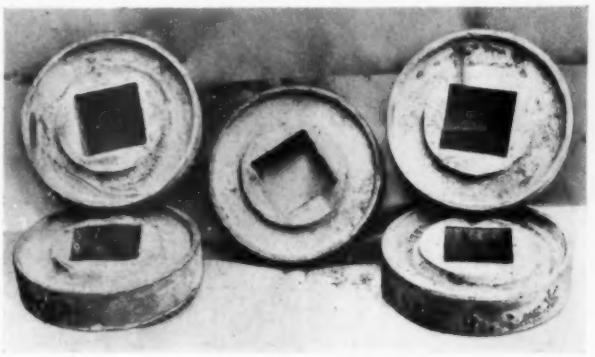


Fig. 6.—Roller castings in Nitricastiron.

The rehardening of nitrarded parts without risk of distortion and scaling is also a facility of great importance, and it is to be anticipated that as the properties of this material become more widely known its uses will extend rapidly.

Measurement of Large Volumes of Gas.

A Curved Tube Manometer.

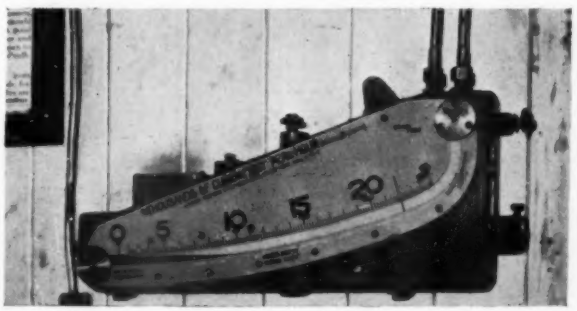
IT is well known that both pitot tube and orifice (modified Venturi tube) devices are now largely used for the measuring of air, town's gas, producer gas, blast furnace gas, and, in fact, almost any gaseous medium. The basic principle is that under correct conditions of design the differential pressure caused either by a pitot tube or an orifice in a pipe line is proportional to the square of the rate of flow of the air or gas. Such meters have many advantages under conditions of low pressure, especially for producer gas and coke oven gas in the iron and steel industries, including convenience, small size, light weight, and low capital cost.

One method of measuring the differential pressure, with direct indication expressed as cubic feet of air or gas per hour, or any other desired figure, is to use the curved tube manometer or sensitive liquid pressure gauge, and considerable interest attaches to the latest designs of manometers of this type supplied by George Kent, Ltd., Luton, Beds.

The inherent difficulty that the flow of the gaseous medium varies as the square root of the differential pressure, giving therefore an extremely small vertical movement at low rates of flow has been overcome by making the manometer tube of the long curved type. Consequently the travel of the liquid in the tube at the lower end is so great for small pressure differences that an equally spaced scale, instead of a square root scale, can be used down to about one-fifteenth of the maximum flow. The standard "Kent" instrument, known as the CT/I type, also is supplied to work at one of three different maximum heads—that is, 0·8 in., 2·0 in., and 4·5 in. water gauge, depending upon the conditions.

As a rule the curved tube is made of celluloid and is fixed in a case in front of a white background with an accurately graduated scale, while the liquid, oil, or other product is dark coloured, giving a very definite meniscus so that readings to plus or minus one hundredth of an inch can be taken without difficulty. On ingenious lines also the manometer is designed so that no appreciable variation of the zero takes place with changes of temperature, a troublesome matter with a number of makes of sensitive manometer. Essentially this is achieved because an automatic compensation is given, due to the fact that the relative expansion or contraction of the liquid, and of the reservoir containing it, balances the alteration of the meniscus in the gauge due to surface tension changes.

Included in the arrangement is a zero adjuster consisting of a displacer operated by a knob through a gland, an equalising valve so as to be able to check the zero at any time, and a spirit level with levelling screws. When the manometer is to be used for gases containing substances which act upon celluloid, such as acetone or ammonia, the



Typical Curved Tube Manometer.

gauge tube is made of glass. In this case, however, should the glass be broken, the instrument has to be sent back to the works for re-calibration.

Various modifications also of the standard CT/I curved tube instrument are available. For example, the CTH/I design is intended for high air or gas pressures over 1 lb. per sq. in. pressure and up to 20 lb. per sq. in., having a special safeguarding device so that the liquid cannot be blown out accidentally while the CTM/I type is a portable form of the instrument for heads up to 0·25 in. water.

Reports on Cold Working of Steel and other Ferrous Metals.

THE increasing practice of cold-working, as applied to steel and other metals, both ferrous and non-ferrous, has given rise to many difficult problems, and although industry rarely waits for scientific instruction in its progress, it became obvious that current practice needs scientific investigation into its methods and inquiry aimed at justifying or improving those methods. Although many of the larger manufacturers have their own research departments, many other firms have no means by which they can scientifically investigate their problems. Feeling that a great need for this form of research existed, the Cutler's Company have rendered valuable assistance in promoting it at Sheffield University, where a department for cold-working of steel was founded. This department has been in existence about three years, during which time research has been carried out on the lines laid down by the Committee.

This publication, issued by the University of Sheffield, contains reports of research work undertaken up to December of last year. These include tests on samples of wire of different sizes and grades submitted by the Patented Steel Rope Wire Association; tests on a bridge wire, an investigation resulting from the failure of heat-treated wire in suspension bridge cables; an investigation into the hardness of wire; the drawing of mild steel bars, with a view to determining the correct type of die which might be adopted as standard; a report on the Johnson bend-testing machine for wire, and also on the Brunton bend-testing machine; and several other investigations which make this publication of considerable value.

It is proposed to issue reports of work done annually, and it is of interest to note that the work for the current year embraces: X-ray examination of cold metals; hardness of steel wire; the fatigue properties of steel wire; the drawing of bars (form of dies); and the rolling of mild steel (effect of annealing on the physical properties).

Catalogues and Other Publications.

Metropolitan Vickers Electrical Co., Ltd., Trafford Park Manchester, have sent us an elaborately produced booklet containing information regarding their research and testing equipment. It contains a description of some of the particular types of apparatus originally designed for their own use. From time to time this company have been asked to construct similar apparatus to that which they use, and they have decided to do so. They assert the apparatus has been so satisfactory in service that it is desirable to widen the facilities they offer. Of these, mention may be made of the Metrovick Vacuum equipment, the X-ray equipment for crystallographic analysis, the cathode-ray oscillograph for ultra-rapid recording, and the resistance-type vacuum furnace. Considerable reference is also made in this booklet to electrical and magnetic research and testing equipment, as well as to equipment for mechanical and metallurgical research and testing.

Henry Wiggin and Co., Ltd., Thames House, Millbank, London, S.W. 1, have published a booklet dealing with the properties of Monel metal, with special reference to power plant equipment. The use of Monel metal for this purpose depends, in part, upon its ability to meet requirements necessitated by the use of high pressures and temperatures, and this booklet describes some of its applications for these purposes. It contains much useful information.

No. 24 of "Lightmetals Research," vol. II., contains abstracts of four papers presented at the A.I.M.M.E. spring meeting, in addition to several other abstracts of articles from technical publications; these include "Recent Advances in the Field of Silumin Castings," "The Effect of Tap Water containing Copper on Aluminium," "The Physical Properties of Aluminium Base Die Casting Alloys," etc., the issue providing a useful guide to work recently published on aluminium and its alloys. It is published by the British Aluminium Co., Ltd., Adelaide House, King William Street, London, E.C. 4.

The English Steel Corporation, Ltd., have added a further brochure to their attractive series dealing with their various specialities. This issue gives information on Visco steel castings, particularly for railway rolling stock. After considerable research a special steel has been developed from which all castings are made, and examples given include automatic couplers, cast-steel yokes, cast-steel bogie side frames and bolsters, axle boxes, etc. Excellent photographic reproductions of the steel foundry and various testing laboratories are included. Applications for copies should be made to Vickers Works, Sheffield.

"Heat Treatment in Gas Fired Liquid Baths" is the title of the British Commercial Gas Association's latest technical publication. Salt baths, lead baths and oil baths for the heat-treatment of both ferrous and non-ferrous metals are dealt with from the practical, and to some extent from the theoretical, point of view, the text being plentifully illustrated with photographs of typical installations throughout the country. Considerable attention is devoted to furnace design and a number of sectional drawings are given. The theory, scope and practice of cyanide hardening are treated in sufficient detail to give the works manager some idea of the applicability of the process to his particular requirements.

The British Oxygen Co., Ltd., Angel Road, Edmonton, London, N. 18, now supply metal spraying equipment, and they have sent us a booklet giving much useful information on the equipment, as well as the process and its applications. Detailed information is given regarding the metal spraying pistol, and those interested in the process will find the booklet of value.

A useful brochure giving information on the various products of McKechnie Bros., Ltd., of Birmingham, has been received. It deals with extruded rods and sections; stampings and pressings; chill-cast bars and ingots in standard non-ferrous alloys. There seems no limit to the application of extruded rods, section and pressings, and since uniformity and soundness of the metals supplied is an important claim, copies of this brochure will be useful to many users.

At the recent annual general meeting of the Institute of Metals the following officers were elected for the year 1933-34:—President, Sir Henry Fowler, K.B.E., LL.D., D.Sc.; Vice-Presidents: C. H. Desch, D.Sc., Ph.D., F.R.S., and Professor R. S. Hutton, D.Sc., M.A.; Members of the Council: Engineer Vice-Admiral Sir Robert Dixon, K.C.B., D.Eng., Wesley Lambert, C.B.E., A.K.C., H. C. Lancaster, A. H. Mundey, A. J. G. Smout, and F. Tomlinson.

The Silver Jubilee meeting of the Institute will be held in Birmingham from September 18 to 21.

Iron and Steel Institute.

(*Continued from page* 22.)

cold-working followed by annealing at the recrystallisation temperature (950° C.), which is sufficient to prevent the formation of carbide films, although the general corrosion resistance is decreased, due to the removal of chromium.

The addition of 4·1% of molybdenum renders the steel magnetic and resistant to decay when air-cooled from 1,050° C., although it is much less resistant when quenched from 1,100° and 1,180° C. The addition of 1·4% of silicon with higher chromium or 0·47% of titanium with 0·59% of tungsten renders the alloy magnetic and fully resistant to intergranular corrosion for up to 100 hours at 600° C.

In view of the evidence presented it was concluded that the addition of elements which form a contracted γ region when alloyed with iron, to a Cr–Ni–Fe austenitic alloy in sufficient quantity to produce δ-iron in the alloy after quenching from 1,000° to 1,200° C. greatly enhances the resistance to intergranular attack. The absence of carbide films in the austenite is due to the δ-ferrite providing disconnected areas in which the carbides can precipitate. Original carbides in the ferrite lower the concentration of carbon in solution and provide nuclei upon which it can be precipitated.

Heating for long periods in the 550° to 900° C. range causes the δ-iron to transform to austenite (non-magnetic).

Recent Developments in Tools and Equipment

New Aluminium Strip Rolling Mill Plant.

IN the production of aluminium strip the type of rolling mill plant employed and its capacity are governed by the desired output and limitations in regard to cost, but as a rule the plant consists of a hot breaking-down mill, and additional cold mills for intermediate and finish rolling. The object of the hot break-down operation is to destroy the as-cast structure of the metal in the ingot form, and produce slabs of suitable thickness and size for further processing by cold rolling. It is an operation which is invariably carried out at a high speed, which involves special equipment. The slabs may, however, be subjected to further hot rolling according to the thickness desired for cold rolling.

An aluminium strip rolling mill plant recently completed by the Brightside Foundry and Engineering Co., Ltd., Sheffield, is designed to produce strip up to 24 in. wide and 0·5 mm. thick, commencing with slabs 120 mm. thick. It includes a hot breaking-down mill, which is designed to break down the slabs to 8 mm. thick; a cold breaking-down or intermediate mill, which further reduces the material to 2 mm. thick; and a cold-finishing mill designed for completing the strip at the thickness desired.

Hot mills for rolling aluminium strip are built in various sizes and designs, and are not standardised. The particular design selected depends upon requirements in regard to output and on the preferences of mill operators and mill

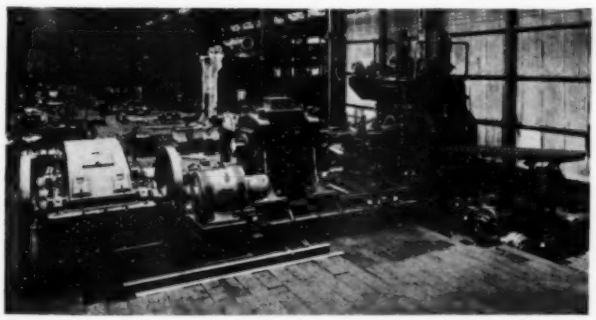


Fig. 1.—Hot breaking-down mill.

engineers. In the mill plant under consideration the hot breaking-down mill, shown in Fig. 1, is a two-high non-reversible mill. It is driven by a 150 h.p. motor operating at a speed of 725 r.p.m. through a double spur reduction gear to give 35 r.p.m. on the rolls.

The mill train comprises the pinion housing unit and roll housing assembly, mounted on continuous girder type beds, the drive being taken through coupling spindles and boxes all counterbalanced and carried in white metal lined cradles. The pinions are of forged steel, having machine-cut double helical teeth, totally enclosed in cast-iron housings fitted with white metal lined chocks. Gravity feed lubrication is employed. The roll housings are of special mixture "Hitest" cast iron, having an ultimate tensile strength of 18–20 tons per sq. in., fitted with cast-steel chocks, white metal lined, internally water cooled, and arranged for pressure-feed lubrication.

The top roll and its chocks are adjusted by a 10 h.p. reversing motor through spur and worm gearing, whilst the "draught" is indicated on a plainly marked dial on the ingoing side of the mill. An interesting feature of this gear is an arrangement for setting the electrical control to give a definite reduction for each pass. The "start" button is pressed for the screw-down motor, and when the roll is lowered to the predetermined point it is automatically stopped. A ladder gives access to the entablature or platform for inspecting the screw-down gear elements. Individual adjustment is obtainable for each screw. An electrically operated tilting table is provided on the outgoing side, operated by worm gears, cranks, and levers. It is of special design, so that when in the top position it

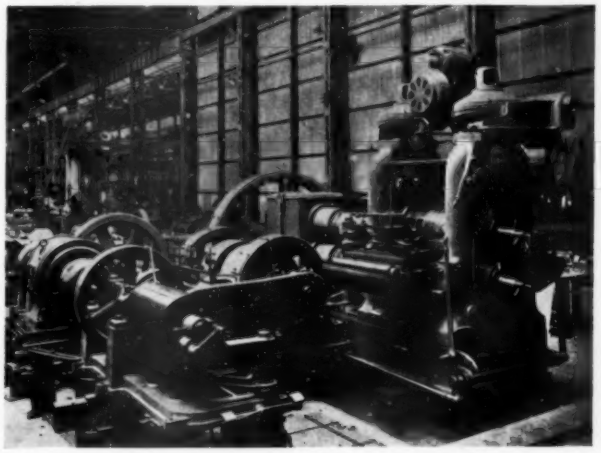


Fig. 2.—Cold breaking-down mill for intermediate rolling.

forms an unbroken incline down which it gravitates to ths ingoing side of the mill. The table is fitted with brase dead rollers. An auxiliary light roller table is also supplied for the ingoing side of the mill for use when rolling long strips. The mill rolls are of chilled cast iron, ground and polished on the barrels to 22 in. diameter × 40 in. face width.

The cold breaking-down or intermediate rolling of aluminium is carried out at room temperature. It is really a roughing operation designed to reduce the thickness of

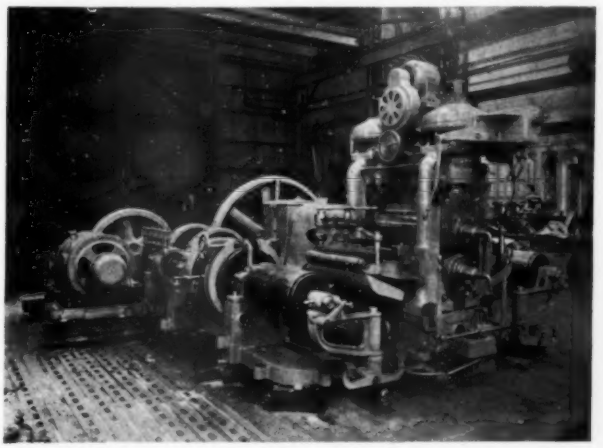


Fig. 3.—Finishing mill.

the product of the hot-mill as rapidly as possible, and prepare the material for the finish rolling. This cold breaking-down mill is of the "Brightside-Schmitz" type, being manufactured by the former concern to designs supplied by Messrs. August Schmitz, of Dusseldorf. This mill, which is shown in Fig. 2, is driven by a 175-h.p. motor through

machine-cut spur gears, and is of the reversing type, the reversals being obtained through friction clutches. The rolls are of hardened forged steel, 17 in. diameter × 32 in. face, internally water-cooled, revolving in water-cooled phosphor bronze steps. The housings are of cast steel, and the screw-down and indicator gear electrically operated by push buttons through an 8 h.p. reversing motor. Individual adjustment is obtainable. Improved type wipers are located on both sides of the mill, and after the final pass the strip is coiled on a coiler having a collapsible drum. The drum spindle is supported in a swivelling bracket to facilitate the stripping of the coils. The coiler is driven by chains and sprockets through a friction clutch and a special device is embodied to ensure the correct tension being given to the strip.

The finishing mill shown in Fig. 3 is substantially of similar design as the intermediate mill, with the exception of having coilers on each side of the mill. The rolls are 14 in. diameter × 32 in. long, driven by a 125 h.p. motor and employing a 6 h.p. motor for the screw-down gear. The whole of the electrical equipment in this strip mill plant was supplied by the English Electric Co., Ltd., of Stafford.

Bearings that Lubricate Automatically.

IT is generally appreciated that the desirable properties of a bearing metal are low coefficient of friction, good thermal conductivity, resistance to abrasive wear, together with sufficient strength and rigidity to withstand the duty to which it is required to be subjected. The anti-frictional and wear-resisting qualities depend almost entirely on the amount, the character, the form, and also on the uniform distribution of the segregated particles. But even the most suitable bearing metal, however well compounded it may be, depends upon an adequate supply of lubricant to reduce friction and wear; only in this way can power be transmitted with minimum loss. Thus, however good the bearing may be, its efficiency is controlled largely by the character and quality of the lubricant applied and the maintenance of the film of oil. Many of the bearing problems are directly attributed to imperfect lubrication, and it has been appreciated for years that a really reliable self-lubricating bearing material, based on scientific principles, would provide a satisfactory solution. Not only would such a material overcome many difficulties, but it would effect considerable saving in upkeep, replacement, and supervision. Numerous efforts have been made in this direction, but the difficulty of combining the desirable properties of the bearing material with ample lubricating life under service conditions has been considerable. A recent development, however, is claimed to have solved these difficulties. This has been registered under the name of "Oilite," and is supplied by the Manganese Bronze and Brass Co., Ltd., Caxton House, Westminster, London, S.W. 1.

Oilite is a bronze material of the copper-tin type, corresponding to that usually employed for anti-frictional purposes, but it is porous, and is impregnated with lubricating oil in such a manner that the pores within the metal act as a reservoir and at the same time ensure the maintenance of a film of oil to the surfaces by the capillary and syphonic action. The material is given a high oil content, ranging between 30 and 40% by volume, and possesses both high strength and ductility. It is of interest to note that bearings and bushes may be manufactured with almost any quality of lubricant, and in the majority of applications the Oilite bearing will contain all the lubricant necessary; where additional lubrication is desired, a reservoir in the housing will ensure the supply. No holes or grooves are required, as the oil passes in filtered form evenly throughout the bearing.

Tests to which Oilite bearings and bushes have been submitted, in comparison with cast-bronze bearings and ball bearings, show remarkably high efficiency, low coefficient of friction, and noiseless operation for an oil consumption that is practically negligible. It is noteworthy that whatever the conditions in the bearing, there is always enough oil present, but never too much. The slightest increase in temperature brings additional oil to the surface of the bearing, which reabsorbs any surplus as cooling takes place. Thus, bearings and bushes manufactured from this material effect considerable saving in the quantity of lubricant used. Tested for shock and impact loads, as a preliminary to their adoption in steering gears, Oilite bearings proved so satisfactory that one motor-car manufacturing company now employ them exclusively for this purpose.

Bearings and bushes of this material have a wide application, particularly in those instances where small bronze bearings are at present in use, and where lubrication is specially difficult, inaccessible, or liable to be neglected, or where bearing pressures are particularly high. In use on a large scale on many thousands of motor vehicles and other engineering applications, its value and reliability have been proved, and its qualities are amplified by the excellent results obtained from extended running tests.

High Speed Foundry Grinding.

IN the fettling of castings low grinding cost is of primary importance, and with the object of achieving this result considerable research and resource have been given to high-speed wheels. A recent development of this character has been effected by the Carborundum Co., Ltd., Trafford Park, Manchester, which has resulted in the production of super high-speed grinding wheels, arranged to run at 9,000 surface feet per minute. These wheels, which may be of Carborundum or Aloxite, are bonded with "Redmanol." This is a synthetic resin or bakelite, which is tough and tenacious, and gives the wheels extreme durability. The wheels are so bonded as to preserve an open, porous structure, giving maximum cutting speed, and at the same time offering great resistance to chipping. They are manufactured to withstand punishing conditions resulting from high-speed fettling, and are claimed to have established new precedents in regard to foundry utility and to have made possible greater economy in the grinding of steel and malleable iron castings in particular.

To effectively operate these high-speed abrasive wheels rigidity is of primary importance in the design of the machines, and for this purpose a special machine has been designed, known as the Redman high-speed floor grinder. It is made in two sizes—24 in. × 3 in. and 18 in. × 3 in.,—which determine the size of wheel most suitable. In each case, however, the machine has an unusually large floor area, which gives it stability, yet the design is such that the framework is out of the way of the operator for any type of foundry work. Very large ball bearings and solid steel spindles provide the necessary safety for carrying the wheels at such a high speed and the bearings are so designed that abrasive dust is excluded from the housings. Lubrication is effected by pressure. An important feature on these machines is the adjustable work rests and rest brackets, which are quickly adjusted to suit the requirements of the work, and also allow for apron grinding. The machines are driven by electric motor which is neatly housed in the base. Two-speed drive is provided, with safety device which prevents maximum diameter wheels running at the top speed. A push-button control panel for starting and stopping is conveniently placed on the machine base.

The whole assembly embodies the accumulated knowledge of years of experience in foundry grinding and has been specially developed to give the speeds required for the successful operation of high-speed fettling wheels.

Recent investigation in the Middle Volga region has resulted in the discovery of rich deposits of copper, with smaller deposits of silver, gold, and platinum. Copper was found at a depth of 12 to 43 metres, the ore containing from 0.87 to 17.6% of copper. The copper is hidden under an "iron cap" stretching for one and a half kilometres. At a depth of 59 metres the geologists found pyrite.

The sum of 300,000 roubles has been advanced to the Volga Geological Trust for further exploration.

Protecting Iron and Steel Against Corrosion.

Many methods are adopted to afford steel protection against corrosion; in this article the most commonly used methods are discussed.

THE rusting of iron and steel is a special form of corrosion which is caused by the combined influences of moisture, oxygen, and carbon dioxide, the process being accelerated by the presence of acidic substances in the atmosphere. It has long been recognised that iron does not rust in pure, dry oxygen, or in pure, dry air; chemical action does take place, however, and a thin oxide film is formed which prevents further access of oxygen to the metal. In practice, however, the rate of corrosion or rusting of iron depends upon the conditions to which it is subjected and which may vary very widely. There are several methods by which the iron is afforded protection, each of which have their special field of usefulness. Whatever the method employed it is founded on scientific principles, and any protective coating applied intentionally should conform to these principles, otherwise the results will be deleterious. This article is confined to two methods, one involving the application of paint and the other a film of a less corrodible metal. In each method the essential conditions for its successful action are uniformity and perfect continuity over the entire surface treated.

Paint.

Probably the most extensively used method for protecting structural steel against rust and corrosion is by the application of red lead paint. The use of structural steel in buildings is now general practice, and wherever these are seen in course of erection it will be noted that the steelwork is almost invariably coated with red lead paint. Thousands of buildings are protected in this way, and one of the latest is the new Cumberland Hotel, Marble Arch, London, W. 1, now under construction, which is to be one of the largest hotels in Europe.

The total weight of structural steel involved in this building, all supplied by Dorman, Long and Co., Ltd., of Middlesborough, is 15,500 tons for the hotel itself, and 1,600 tons for the annexe and subway, and the whole of this steel has been given a priming coat of red lead paint for protection against rust. Red lead owes its efficiency for this purpose to three reasons. In the first place it forms a heavy, dense paint film, affording protection from air and moisture, the weight of the paint averaging about 35 lb. to the gallon. Unlike most paint materials, however, red lead (triplumbic tetroxide, Pb_3O_4) is chemically active, and two different sets of beneficial reactions are involved. First, it is an oxidising agent, and there is formed on the surface of the steel a "passive" film of oxide of iron which is strongly resistant to the passage of the local electric currents regarded as essential to corrosion, according to the electro-chemical theory, as well as to the action of the atmosphere generally. Further, red lead is a basic substance and therefore neutralises traces of acid in the atmosphere, such as sulphuric, sulphurous, nitric, nitrous, and hydrochloric, which increase very considerably the rapidity of corrosion—that is, red lead paint, in addition to covering the surface of the steel with a layer which is protective for physical reasons, also acts as an inhibiter or retarder of rust and corrosion in two different directions, due to its oxidising and basic character. Consequently, the full advantages of structural steel can be utilised, since the inherent disadvantage—that of rusting—is eliminated.

The recent celebration of the centenary of the French engineer, Alexandre Gustav Eiffel, famous as the originator of the Eiffel towers in Paris and Blackpool, calls to mind the efforts made to protect and preserve these steel structures. The tower in Blackpool, for instance, erected by Heenan and Froude, Ltd., of Manchester, in 1891-2, has caused no trouble in this direction, since red lead paint is used exclusively for the ground coat of all the steelwork, about 10 tons of paint being required for one coat. The Blackpool Tower Co., Ltd., state that, by adopting this method of protection, the steelwork is still in excellent condition after the long exposure to wind and rain, and the salt spray from the Irish Sea.

Only two examples have been chosen to show the value of this method of protection, which has become standardised for bridges, lighthouses, pit-head gear, aerials for high-tension transmission lines, and many other exposed structures. Not all iron and steel parts can be effectively protected by paint, and the work of repainting is sometimes costly, necessitating the use of some other method

The Eiffel Tower at Blackpool.

to give the required security. In many of these cases the use of a metal coating has advantages, and a coating of zinc, by a process called galvanizing, offers resistance against corrosion for a long period.

Galvanizing.

The term "galvanizing" is usually understood to apply to the "hot" galvanizing process, in which the articles to be treated are immersed in a bath of molten zinc, and is the process with which we are immediately concerned. This process is totally distinct from the electro-galvanic method, in which a thin coating of zinc is deposited by the action of an electric current.

Hot galvanizing is recommended wherever possible,

because this process results, when correctly carried out, in the production of an even, substantial, and homogeneous coating which is corrosion-resisting, pliable, and firmly adherent to the iron and steel base.

The anti-corrosive action of galvanized castings depends entirely on their weather-resisting properties. When properly deposited, these coatings hermetically seal the surface and completely prevent the access of air to the underlying iron or steel. The practice of coating iron with zinc has, therefore, nothing to do with the relative electrolytic properties of zinc and iron, but is based on the fact that zinc itself is a highly weatherproof metal. After a short exposure to the atmosphere, zinc becomes coated with an extremely dense and insoluble coating of zinc oxide and basic zinc carbonate, which itself protects the underlying zinc from the further action of atmospheric agencies.

From another point of view—that of adherence,—the protective coating obtained by the hot galvanizing process is immeasurably superior to many coatings which quickly crack and peel off. The zinc coating becomes definitely alloyed with the surface of the iron, and it is interesting to know that this coating is composite in character and really consists of several layers merging one into the other, so that there is no really sharp boundary between the iron surface underneath and the pure zinc above. The hot galvanizing process is therefore one of the most successful methods of protecting iron and steel from corrosion, and it has economical advantages.

A New Rotary Oil-fired Sand Dryer.

(Patent applied for)

THIS machine has been designed primarily for drying sea sand for foundry use, but is also suitable for dealing with other types of sand. It is built on different lines to the "Titan" coke-fired dryer, which has been available for ten years and has given excellent results.

The machine is friction driven, the required power (3 h.p.) being transmitted from the shaft, to which a pulley is fitted, through a pair of pinions to the driving shaft. Fixed on this shaft are two rollers off which the machined paths fitted to the drum are driven. A pair of idle rollers are fixed at opposite sides of machine.

The wet sand is fed into a fixed chute by hand, or from conveyer or elevator. It is then picked up by a series of scoops attached to the rotating drum or cylinder. The drum is slightly inclined from the feed end to the discharge end. A series of sections is fitted internally on the outer drum, and externally on the inner drum. The sand is picked up by the sections, and as the drums revolve a constant stream of sand is falling ; this process continues during the passage of the sand from the feed end to the discharge end of the drum. A fixed casing or box encloses the discharge end of the drum around which a sieve is fixed. The dried fine sand passes through the sieve and into a chute attached to the bottom of the fixed casing. Sand too coarse to pass through the sieve is discharged over the end of the drum into a chute fixed at the end of casing.

The heat is obtained by means of an oil burner fitted into a brick-lined combustion chamber carried on the fixed end of dryer. This chamber projects into the rotating centre tube or drum of the dryer. The flame passes through the centre tube or drum and is drawn back by natural draught between the centre and outer drums to chimney.

The standard machine is capable of dealing with 3½ to 4 tons of sand, with a moisture content of 10% to 12% per hour, and takes for this duty approximately 2½ gals. of fuel oil per hour. It has been thoroughly tested out in a large foundry producing automobile castings, and has proved exceptionally efficient and economical. Designed and manufactured by the Constructional Engineering Co., Ltd., Titan Works, Birmingham, this machine marks a distinct development in sand drying apparatus for foundry use.

Business Notes and News

Some Orders Placed for the New Corby Steelworks.

Messrs. Stewarts and Lloyds, Ltd., have, on the advice of their consulting engineers, Messrs. H. A. Brassert and Co., Ltd., placed orders for a large modern by-product coking installation to be built at their new steelworks at Corby, Northamptonshire.

The oven battery, coke-screening, and coke-handling plant will be constructed by the Woodall-Duckham Co., London, the by-product recovery plant by Messrs. W. C. Holmes and Co., Ltd., Huddersfield, and the coal-washery and coal-handling plant by Messrs. Simon-Carves, Ltd., Stockport.

The coke-oven battery will comprise 35 Becker ovens heated by blast-furnace gas, this type of oven being the only one actually operating on blast-furnace gas in Great Britain ; coal storage bin, a complete set of oven machines, and central quenching station. The coke-screening and handling plant comprises wharf, screening station, and belt conveying systems. The by-product plant will consist of gas exhausters, coolers, ammonia recovery plant for the production of sulphate of ammonia, and benzol recovery and rectification plant for the production of refined motor spirit ; while the coal-washery and coal-handling plant comprises a coal washery of 125-tons per hour capacity, with a dust-extraction plant and coal storage, blending, handling, and crushing plant.

Copper Development Association.

On the initiative of the Rhodesian and Canadian copper producers a meeting of leading representatives of the copper trade was held in London on Monday, when it was decided to form a copper development association. The new association will have as its object the collection of technical and cognate information on the use of copper and the dissemination of this information to consumers and potential users of copper. The association will be under the control of a council on which the various interests will have representation, and immediately after incorporation will start work with offices at Thames House, Millbank, London, S.W. 1.

Beilby Memorial Awards.

From the interest derived from the invested capital of the Sir George Beilby Memorial Fund, at intervals to be determined by the administrators representing the Institute of Chemistry, the Society of Chemical Industry and the Institute of Metals, awards will be made to British investigators in science to mark appreciation of records of distinguished original work, preference being given to investigations relating to the special interests of Sir George Beilby, including problems connected with fuel economy, chemical engineering, and metallurgy.

Awards will not be made on the result of any competition, but in recognition of continuous work of exceptional merit, being evidence of distinct advancement in knowledge and practice. Two awards of £250 each were made in 1930, and two awards of £105 each in 1932.

The administrators of the Fund—the Presidents, the Honorary Treasurers, and the Secretaries of the three participating Institutions—will meet in June next, and will be glad to have their attention directed to outstanding work of the nature indicated. Correspondence on this subject should be addressed to the Convener, Sir George Beilby Memorial Fund, the Institute of Chemistry, 30, Russell Square, London, W.C. 1, *not later than June* 1, 1933.

Demonstrations of Electric Heat Treatment.

By arrangement between the City of Leeds Electricity Department and the Yorkshire Electric Power Co., an exhibition and demonstration of electric heat-treatment furnaces and equipment will take place at the Leeds Corporation Electric Power Station, Redcote Road, Kirkstall Road, Leeds, from May 17 to 27 inclusive. The furnaces, some of which will be in production use by well-known firms, include a wide variety suitable for different classes of work, such as automatic steel hardening, box type for general heat-treatment, continuous furnaces, tempering furnaces with forced air circulation, high temperature furnaces, and also laboratory furnaces. Admittance to the exhibition is free to those interested in heat-treatment equipment and operations.

SULPHATE ROASTING OF COPPER ORES.

A GREAT deal of work has been done with the roasting and subsequent wet extraction of copper from ores, but the process cannot yet be said to have attained a very wide application. An investigation on the subject has been carried on by Edgar A. Ashcroft since 1928, and is still in progress. This investigation has already resulted in what appears to be a considerable clarification of the mechanism of roasting operations, as well as in devising a connected series of operations, for the wet recovery of copper, either alone or especially when in association with zinc or nickel; and also a new modification of an old and theoretically very promising form of electrolytic recovery of copper which has never previously attained technical success.

This research was started with the idea that copper ores, whether oxidised minerals or sulphides, might, by judicious and controlled admixtures of the two classes, be so roasted together as to render all, or practically all, the copper in both oxides and sulphides water soluble as copper sulphate; and to render practically all the iron insoluble as ferric oxide.

The theory formulated is briefly as follows: Reaction in roasting proceeds to the formation of sulphates and not of oxides, the latter being a secondary formation: and SO_2 is likewise a secondary product. Iron oxide probably acts as an efficient catalyser in the formation of copper, zinc, and nickel sulphates.

Iron is probably the only element which by reason of the great heat of formation of its higher oxide Fe_2O_3, will readily yield up its acid radical to any nearby basic material, such as oxidised copper or basic gangue constituents, and itself pass wholly to oxide in a sufficiently oxidising atmosphere. As a corollary, iron sulphate is not decomposed normally at a temperature so far below the decomposition temperature of copper sulphate that a mere roasting at a carefully regulated temperature may be employed to produce soluble copper and insoluble iron quantitatively or nearly so. As a matter of fact, none of these sulphates is completely decomposed if heated alone at any temperature (*e.g.*, at 700° to 800° C. or even higher), which could possibly be employed in an ordinary roasting furnace for the production of completely soluble copper either as acid soluble oxide or as water soluble sulphate.

At any temperature above 550° C. or thereabouts, formation of cupric ferrite, $CuOFe_2O_3$, begins when copper oxide and iron oxide are brought into juxtaposition, and even at 700° C. such formation is prohibitively rapid. It is of course well known that such ferrites are insoluble in any practical acid leaching solution. Further, the ordinary rabbled furnace is inimical to the production of "all water soluble" copper sulphate by reason of the omnipresent reaction: $CuSO_4 + CuS + 2O = 2CuO + 2SO_2$.

This reaction in well rabbled charges begins at almost as low a temperature as the oxidation of sulphur to form sulphates begins. Certainly it is in full swing at 400° C., whilst the best temperature to employ in stationary charges is 600° C. or thereabouts. A similar reaction to the above, resulting in the decomposition of already formed sulphates, is apt to occur in the presence of carbon or of any reducing gas, such as flue gas, thus: $CuSO_4 + CO = CuO + SO_2 + CO_2$.

From this underlying theory a cyclic copper leaching and recovery process has been developed which is described by the author in a paper presented at the recent meeting of the Electrochemical Society, held at Montreal, Canada. Laboratory tests on Rhodesian ores show that the roasting of copper ores should be directed primarily to the formation of water-soluble sulphates, employing oxygen gas in place of air, if necessary, to bring about the reactions rapidly and completely. Sulphate formation begins at about 370° C. and proceeds rapidly at about 600° C. The ore is carefully selected or mixed so that the charge for the roaster contains an equivalent basic carbonate or oxide for every equivalent of sulphur present. The roasting reactions are then "self-heating." The $CuSO_4$ obtained upon leaching may be either crystallised out and sold as "blue stone," or better still, cement copper is produced, and upon leaching this, pure electrolytic copper is recovered by the author's new chloride process. This process is claimed to be a marked improvement over the old Hoepfner process. In place of building up the Cu content of the spent electrolyte by passing it over copper sulphide ore, the author uses cement copper. The cells are equipped with graphite anodes and there is a heavy covering of paraffin oil over the surface of the bath to reduce air oxidation of the cuprous chloride to a minimum. The solution contains 150 g./L. Cu, 300 g./L. Cl plus a little H_2SO_4. The current density is 1·5 to 2·5 amp./dm.^{2}; cell voltage, 0·8 to 1·05.

The Chemistry of Indium.

INDIUM, one of the rarest of elements, was discovered in 1867 by Reich and Richter by means of its spectrum, which is characterised by two predominant purple lines. These still serve as the most sensitive test for this metal. Through the kindness of Mr. L. R. Westbrook and the Grasselli Chemical Co. we were furnished with sufficient amounts of metallic indium and indium oxide to enable us to carry on the present investigations. In the past, the work with indium had to be done with quite small quantities, so that it seemed highly desirable to check the chemistry of this metal with larger amounts that were so fortunately put at our disposal.

Indium has a pronounced tendency to form basic salts that are only sparingly soluble in water. The basic chloride, however, is soluble in boiling water. In general, indium salts behave chemically like corresponding aluminium salts. Thus, when solutions of indium salts were treated with alkali carbonates, the precipitate formed was found to be indium hydroxide to the extent of about 95%. The hydrolysis of indium carbonate is consequently effected very readily, like that of aluminium carbonate.

A series of tests with indium chloride solutions and less commonly used reagents was made by Alfred W. Downes and Louis Kaklenberg, in the hopes of finding some peculiar characteristic chemical reaction of indium which might serve for its ready detection, and the results were presented at the sixty-third general meeting of the Electrochemical Society, held at Montreal, Canada.

The chemical study revealed that the metal exhibits no specially striking chemical reactions as compared with lead, cadmium, aluminium, and zinc; so that by far the best means of detecting indium is still the spectroscope. Indium has a special tendency to form basic salts which are sparingly soluble in water. As in the case of aluminium, alkali carbonates precipitate the hydroxide and not the carbonate. Both the replacing power and the electrode potentials indicate indium to be a little less noble than tin in the electrochemical series. The potential behaviour is similar to that of cadmium. Gases affect the potential of indium but very slightly indeed. Indium, like tin, makes alloys harder and stronger. Indium hydride is a dark brown powder that decomposes completely when heated to 330° C. Hydrogen passed over hot indium is but slightly activated thereby. Indium decomposes CO_2 at 560° C., forming indium oxide and CO, but the action is far less vigorous and extensive than that obtained with tin under like conditions.

Mr. A. Glynne Lobley, general manager of Birmingham Electric Furnaces, Ltd., is shortly to visit the Electric Furnace Co. of Salem, and Messrs. C. I. Hayes, Inc., as well as other firms in America, for the purpose of augmenting by discussion and inspection the advantages of the agreement entered into with these firms some time ago. Mr. Lobley is due to return about the end of June, and it is believed his visit will do much to cement the amiable relations existing between the electric furnace industry in both countries.

MARKET PRICES

ALUMINIUM.

98/99% Purity	£95	0	0

ANTIMONY.

English	£37 0 0 to £42	10	0
Chinese	26	0	0
Crude	19	0	0

BRASS.

Solid Drawn Tubes	lb.	8¼d.
Brazed Tubes	„	10¼d.
Rods Drawn	„	7⅞d.
Wire	„	7⅞d.
*Extruded Brass Bars	„	4½d.

COPPER.

Standard Cash	£33	16	6
Electrolytic	37	12	6
Best Selected	36	5	0
Tough	35	15	0
Sheets	63	0	0
Wire Bars	37	15	0
Ingot Bars	37	15	0
Solid Drawn Tubes	lb.	9½d.	
Brazed Tubes	„	9½d.	

FERRO ALLOYS.

‡Tungsten Metal Powder	lb.	0	1	9
‡Ferro Tungsten	„	0	1	6
NOMINAL: Ferro Chrome, 60-70% Chr. Basis 60% Chr. 2-ton lots or up.				
2–4% Carbon, scale 12/– per unit	ton	34	2	6
4–6% Carbon, scale 7/6 per unit	„	24	0	0
6–8% Carbon, scale 7/6 per unit	„	21	17	6
8–10% Carbon, scale 7/3 per unit	„	21	0	0
§Ferro Chrome, Specially Refined, broken in small pieces for Crucible Steelwork. Quantities of 1 ton or over. Basis 60% Ch. Guar. max. 2% Carbon, scale 11/0 per unit	„	33	17	6
Guar. max. 1% Carbon, scale 13/6 per unit	„	37	17	6
§Guar. max. 0·7% Carbon, scale 15/– per unit	„	42	17	6
‡Manganese Metal 96–98% Mn.	lb.	0	1	4
‡Metallic Chromium	„	0	2	8
§ Ferro-Vanadium 25–50%	„	0	12	8
§ Spiegel, 18–20%	ton	7	10	0
Ferro Silicon— Basis 10%, scale 3/– per unit	ton	5	17	6
20/30% basis 25%, scale 3/6 per unit	„	8	10	0
45/50% basis 45%, scale 5/– per unit	„	13	15	0
70/80% basis 75%, scale 7/– per unit	„	19	0	0
90/95% basis 90%, scale 10/– per unit	„	30	0	0
§ Silico Manganese 65/75% Mn., basis 65% Mn.	„	14	17	6
§ Ferro-Carbon Titanium, 15/18% Ti	lb.	0	0	6
Ferro Phosphorus, 20–25%	ton	17	17	6

FUELS.

Foundry Coke—						
S. Wales	£1	0	0 to	1	2	6
Scotland	—			1	8	0
Durham	1	1	0 to	1	5	0
Furnace Coke—						
Scotland	—			1	5	6
S. Wales	0	16	0 to	0	16	6
Durham	0	13	0 to	0	13	6

GUN METAL.

*Admiralty Gunmetal Ingots (88 : 10 : 2)	£48	0	0
*Commercial Ingots	37	10	0
*Gunmetal Bars, Tank brand, 1 in. dia. and upwards	lb.	0	0 8
*Cored Bars	„	0	0 10

LEAD.

Soft Foreign	£12	1	0
English	13	10	0

MANUFACTURED IRON.

Scotland—				
Crown Bars, Best	£10	5	0	
N.E. Coast—				
Rivets	11	0	0	
Best Bars	10	10	0	
Common Bars	10	0	0	
Lancashire—				
Crown Bars	9	15	0	
Hoops	£10 10 0 to	12	0	0
Midlands—				
Crown Bars	£9 15 0 to	10	0	0
Marked Bars		12	0	0
Unmarked Bars		—		
Nut and Bolt Bars	£8 7 6 to	8	12	6
Gas Strip		10	12	6
S. Yorks —				
Best Bars		10	10	0
Hoops	£10 10 0 to	12	0	0

PHOSPHOR BRONZE.

*Bars, "Tank" brand, 1 in. dia. and upwards—Solid	lb.	8d.
*Cored Bars	„	10d.
†Strip	„	10½d.
†Sheet to 10 W.G.	„	10¾d.
†Wire	„	11¾d.
†Rods	„	11d.
†Tubes	„	1/3½
†Castings	„	1/1¼

†10% Phos. Cop. £30 above B.S.
†15% Phos. Cop. £35 above B.S.
†Phos. Tin (5%) £30 above English Ingots.

PIG IRON.

Scotland—			
Hematite M/Nos.	£3	6	0
Foundry No. 1	3	7	6
„ No. 3	3	5	0
N.E. Coast—			
Hematite No. 1	2	19	6
Foundry No. 1	3	5	0
„ No. 3	3	2	6
„ No. 4	3	1	6
Silicon Iron	3	5	0
Forge	3	1	6
Midlands—			
N. Staffs Forge No. 4	3	1	0
„ Foundry No. 3	3	6	0
Northants—			
Foundry No. 1	3	5	6
Forge No. 4	2	17	6
Foundry No. 3	3	2	6
Derbyshire Forge	3	1	0
„ Foundry No. 1	3	9	0
„ Foundry No. 3	3	6	0
West Coast Hematite	3	6	0
East „ „ No. 1	3	0	0

SWEDISH CHARCOAL IRON AND STEEL.

Kr. per English ton @ 18–16 to £1 approximately.

Pig Iron Kr. 90
Billets Kr. 280-290 £15 10 0–£16 0 0
Wire Rods Kr. 265-320 £14 12 6–£17 12 6
Rolled Bars (dead soft) Kr. 185-210 £10 4 0–£11 11 0
Rolled Charcoal Iron Bars Kr. 290 16 0 0
All per English ton, f.o.b. Gothenburg.

SCRAP METAL.

Copper Clean	£23	0	0
„ Brazier	19	0	0
„ Wire		—	
Brass	16	0	0
Gun Metal	20	0	0
Zinc	9	0	0
Aluminium Cuttings	74	0	0
Lead	9	10	0
Heavy Steel—			
S. Wales	2	5	0
Scotland	1	18	0
Cleveland	1	15	0
Cast Iron—			
Midlands	2	0	0
S. Wales	2	3	6
Cleveland	1	17	6
Steel Turnings—			
Cleveland	1	11	6
Midlands	1	4	6
Cast Iron Borings—			
Cleveland	1	2	6
Scotland	1	12	0

SPELTER.

G.O.B. Official		—	
Hard	£13	0	0
English	15	17	6
India	14	10	0
Re-melted	15	10	0

STEEL.

Ship, Bridge, and Tank Plates Scotland	£8	15	0
North-East Coast	8	15	0
Midlands	8	17	6
Boiler Plates (Land), Scotland	9	0	0
„ „ (Marine) „		—	
„ „ (Land), N.E. Coast	10	0	0
„ „ (Marine) „	10	10	0
Angles, Scotland	8	7	6
„ North-East Coast	8	7	6
„ Midlands	8	7	6
Joists	8	15	0
Heavy Rails	8	10	0
Fishplates	12	0	0
Light Rails £8 10 0 to	8	15	0
Sheffield—			
Siemens Acid Billets	9	2	6
Hard Basic £8 2 6 and	8	12	6
Medium Basic £6 12 6 and	7	2	6
Soft Basic	6	0	0
Hoops £9 10 0 to	9	15	0
Manchester Hoops £9 0 0 tp	10	0	0
Scotland, Sheets 24 B.G.	10	5	0

HIGH SPEED TOOL STEEL.

Finished Bars 14% Tungsten	lb.	2/–
Finished Bars 18% Tungsten	„	2/9
Extras		
Round and Squares, ½ in. to ¼ in.	„	3d.
Under ¼ in. to ⅛ in.	„	1/–
Round and Squares 3 in.	„	4d.
Flats under 1 in. × ⅜ in.	„	3d.
„ „ ½ in. × ¼ in.	„	1/–

TIN.

Standard Cash	£185	15	0
English	187	5	0
Australian	195	12	0
Eastern	202	10	0
Tin Plates I.C. 20 × 14 box	0	16	0

ZINC.

English Sheets	£24	0	0
Rods	26	0	0
Battery Plates		—	
Boiler Plates	22	0	0

* McKechnie Brothers, Ltd., quoted May 10. † C. Clifford & Son, Ltd., quoted May 10. ‡ Murex Limited, quoted May 10.
Subject to Market fluctuations. Buyers are advised to send inquiries for current prices.
§ Prices quoted May 10, ex warehouse.